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# TENSES IN COMPOSITIONAL SEMANTICS

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## 1. AIM OF THIS ARTICLE

Most scholars assume that the Present in matrix clauses denotes the speech time, but there is little agreement on the meaning of the Past. I am aware of at least three approaches:

(i) Past is an existential quantifier that instantiates the embedded VP to some time before

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the speech time; this view is attributed to tense logic, e.g. (Prior, 1967).<sup>1</sup>

(ii) Past is a referring term denoting some contextually salient time before the speech time; this semantics is attributed to (Partee, 1973).<sup>2</sup>

(iii) Past is a predicate that applies to a time  $t$  and says that  $t$  is before the speech time; this view originates perhaps with (Dowty, 1979).<sup>3</sup>

I think that each of these approaches can be made to work with auxiliary assumptions. Complications will arise, however, as soon as we study the semantics of Tense in embedded constructions. Here tenses either will contain a bound variable or they are simply bound variables and none of the above approaches can be applied.

To see what is necessary for a successful semantic treatment of Tense therefore requires the study of Tense in subordinate constructions such as relative clauses, verbs of attitude and temporal adjunct clauses. Furthermore we have to make sure that Tense interacts in a correct way with temporal adverbs, with negation, and quantification.

In this paper I cannot evaluate the different formal approaches I am aware of. I will present the approach in (Heim, 1997), which is in the spirit of tense logic. The approach will be combined with a theory that has subordinate Tense as a bound pronoun. Combined with a theory of feature transmission under binding (cf. e.g. (Heim, 2005)), the approach contains the essential ingredients for an adequate theory of tense in English and other languages, I believe. I will also refer to a number of other proposals made in the literature; but it should be clear that in such a short paper, it is impossible to do justice to the entire literature on tense in compositional semantics; there may be other work of equal importance.

The structure of the article is as follows. Section 2 introduces the ontology of time together with some terminology. Natural language requires a distinguished time  $s^*$ , the speech time (“origo”). Times will be intervals composed of moments. Section 3 is about the relation of predicates of natural language to time. I will assume that each basis predicate has exactly one time argument or an argument of something that uniquely determines a time. I will illustrate this claim by a discussion of the Vendler Aktionsarten. Section 4 introduces an

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<sup>1</sup> The indefinite approach is used in (Ogihara, 1989) and (Kusumoto, 1999), among others.

<sup>2</sup> Followers of this approach are (Abusch, 1994) and (Kratzer, 1998), among many others.

<sup>3</sup> Systems along these lines are found in (von Stechow, 1995) and (Musn, 2002) among others.

extensional semantic framework; the intensional version is introduced in section 11.2, where attitudes are treated. Section 5 introduces the semantics for Present and Past and those of the temporal auxiliaries. Section 6 deals with the syntax/semantics interface: a semantic tense transmits its feature to a finite verb under binding. Section 7 treats the interaction of Tense with temporal adverbs such as *yesterday*, *at six o' clock* and asymmetric temporal quantifiers like *on every Sunday*. Section 8 discusses the referential theory of tense and the Partee Problem; it defends an indefinite semantics for the Past. Section 9 introduces contextual restriction for tense. Section 10 contains remarks on the scope interaction between Tense and quantifiers and negation. Section 11 treats tense in subordinate constructions.

## 2. THE ONTOLOGY OF TIME

For doing semantics it not necessary to say precisely what times are.<sup>4</sup> It is enough to make some structural assumptions that clarify how language speaks about time. The great majority of semanticist cling to the idea of a time line that consists of ordered time intervals. The line is composed of moments that are ordered by the “before” relation  $<$ , which is a linear ordering, i.e. for two moments  $m_1, m_2$  we have:  $m_1 < m_2$  or  $m_2 < m_1$  or  $m_1 = m_2$ . The converse relation “after” is denoted by  $>$ , i.e.,  $t > t'$  iff  $t' < t$ . Most semanticists assume that time is continuous, i.e., the moments are similar to real numbers (see, e.g. (Klein, 2008a)). (Dowty, 1979) assumes discrete time because the definition of his BECOME-operator, which is used for the analysis of achievements/accomplishments, requires that for each time there is exactly one next time. Section 3.2 shows a way to define achievements in a continuous time. So time can be continuous.

The  $<$ -relation is extended in a natural way to intervals: The interval  $t$  is before the interval  $t'$  if each moment in  $t$  is before any moment in  $t'$ . Time intervals  $t$  are assumed to be “convex” in the following sense: if  $m_1$  is the first moment in  $t$  and  $m_2$  is the last moment in  $t$ , then any moment between  $m_1$  and  $m_2$  is in  $t$  as well. This terminology assumes that time intervals are closed, i.t. that each  $t$  has the form  $[m_1, m_2] = \{m \mid m_1 \leq m \leq m_2\}$ , where  $m_1$  is the left bound of  $t$  –  $lb(t)$  – and  $m_2$  is the right bound of  $t$  –  $rb(t)$ .

Intervals may overlap, which is represented by  $O$ , or they may stand in the subinterval relation ( $\sqsubseteq$ ) or proper subinterval relation  $\subset$ . And, of course we may form the union  $t \cup t'$  of

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<sup>4</sup> Personally, I think that times are equivalence classes of stretches of possible worlds that occur at the same time. The authors of (Kamp and Reyle, 1993) hold the view that times are equivalence classes of events that occur at the same time. This is much the same.

the two times  $t$  and  $t'$ , where  $t$  and  $t'$  should be contiguous or overlapping. Similarly, we can intersect two times i.e., form the  $t \cap t'$  from the times  $t$  and  $t'$ . The relations  $O$  and  $\cup$  may be defined on the basis of  $\subseteq$ . Since moments do not play any role in time semantics, we will conceive of times as intervals.

Time spans have length/duration, which is measured by means of an appropriate unit: second, hour, day. Lengths satisfy the usual conditions for distances. In this article duration won't play a role.

The notion of tense in natural language is a deictic category, i.e., a tense is always related to the deictic centre, the speech time  $s^*$  (called *origo* by Klein).

Taken together, we are assuming the following *time structure*:

(1)  $\langle M, T, <, \subseteq, QU, s^* \rangle$

where  $M$  are the time points,  $T$  (the time spans) is the set of closed intervals formed from time points;  $<$  is the before relation defined both for points and for intervals,  $\subseteq$  is the subinterval relation,  $QU$  is a function assigning to each time interval a length,  $s^*$  is the speech time.<sup>5</sup>

### 3. VENDLER AKTIONSPORTEN AND THE TIME ARGUMENT

In this section I want to clarify the following questions:

1. Do we need points of time/moments? (Yes.)
2. Is time discrete or a continuum? (Possibly a continuum.)
3. How many time arguments has a predicate? (Depends. One or two.)

I try to give answers by recapitulating what has been said in the literature about the temporal properties of Vendler Aktionsarten.

Every semanticist working on tense assumes different temporal properties for the so-called *Vendler Aktionsarten* for verbs and adjectives: States, Achievements, Accomplishments, and Activities; see (Vendler, 1957) There is agreement that these properties are not properties of verbs (or adjectives) in isolation but of VPs. Which Aktionsart is expressed by a VP is compositionally determined from the meanings of its parts. Nevertheless, the temporal structure of the lexical entry should be appropriate for the

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<sup>5</sup> The notation  $s^*$  for the speech time is used by many authors, e.g. (Ogihara, 1996),  $QU$  for time measure is used in (Kamp and Reyle, 1993).

composition. For the following definitions we assume temporal properties P of type it.<sup>6</sup>

### 3.1. States

States are typically expressed by adjectives. The semantics of states poses a serious problem for the now popular idea that language only speaks about time intervals. We will say that states are predicates of moments. Look first at the following classic definition, which is due to (Tailor, 1977).

(2) **States.** The temporal property P is a *state* (or stative) if for every time t:

$$P(t) \leftrightarrow (\forall t' \subseteq t) P(t')$$

In other words, states have the *subinterval property*. The tenseless VP **the shop be open** (called lexical content by (Klein, 2008b)) is a state: if the shop is open at the interval  $t = [9 \text{ a.m.}, 7 \text{ p.m.}]$ , then the shop is open at any subinterval thereof. The condition raises the question of what the meaning of **open** should be. There are two options: (i) the subinterval property could be implemented in the meaning; (ii) the adjective could be defined for time moments and a covert logical operation could extend the predicate to intervals.

(3) **open**

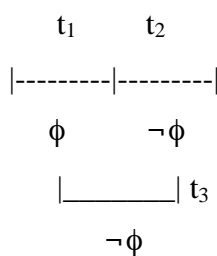
a.  $\llbracket \text{open} \rrbracket = \lambda t \in T. \lambda x. (\forall t' \subseteq t) x \text{ is open at } t'$ . (interval semantics)

b.  $\llbracket \text{open} \rrbracket = \lambda m \in M. \lambda x. x \text{ is open at } m$ . (point semantics)

Consider the LF of the VP under the first alternative.

(4)  $\llbracket \text{the shop open} \rrbracket = \lambda t. (\forall t' \subseteq t) \text{ the shop is open at } t'$ .

This meaning raises the question of how it combines with negation. Consider the VP **the shop be not open** and abbreviate this property as  $\phi$ . Adopting the interval semantics (3a), the negated VP  $\neg\phi$  is true of an interval t if  $\phi$  is false of at least one subinterval of t. This is a very weak condition. Consider the following situation with abutting intervals  $t_1$  and  $t_2$ :



The subinterval property entails that  $\phi$  is true at  $rb(t_1) = lb(t_2)$ . The semantics predicts that  $\neg\phi$

<sup>6</sup> Types are introduced systematically in section 4.

is true at the interval  $t_3$ , though at the first half of  $t_3$   $\phi$  is true.  $\neg\phi$  would even be true of  $t_3$  if  $t_3$  were a final subinterval of  $t_1$ , i.e., only the last point of  $t_3$  would make  $\phi$  false.

Now, consider the VP **the shop is not open from 9 A.M. to 8 P.M.** . The prevailing reading is that the shop is not open, i.e. closed, throughout the interval [9 a.m., 8 p.m]. We cannot express this by means of the entry (3a). Suppose therefore that we have the covert adverb **THR**(oughout):

$$(5) \quad \llbracket \mathbf{THR}_{i(mt,t)} \rrbracket = \lambda t. \lambda P_{mt}. (\forall m \in t) P(m)$$

The VP **the shop be not open** can have two logical forms:

$$(6) \quad \lambda t. \mathbf{not}_{tt} \mathbf{THR}(t) \mathbf{the\_shop \ open}$$

$$= \lambda t. \neg(\forall m \in t) \text{ the shop is open at } m$$

This is the reading we get with the interval semantics.

$$(7) \quad \lambda t. \mathbf{THR}(t) \mathbf{not}_{tt} \mathbf{the\_shop \ open}$$

$$= \lambda t. (\forall m \in t) \text{ the shop is not open at } m$$

This is the intuitively prevailing reading. Since I don't see how the second reading can be obtained from the interval semantics, I will assume that the *mt* ("moment to truth-value") semantics is the correct version.

States are typically expressed by (stage-level) adjectives: **sick, drunk, happy, asleep, ...** Locative prepositions express states as well: **the book be on the table** means  $\lambda t$ .the book is on the table throughout  $t$ . The so called object-level stative verbs, e.g. **know, like** express states as well (cf. (Dowty, 1979: p. 180)): **Wolfgang like Eva** means  $\lambda t$ .Wolfgang likes Eva at throughout  $t$ . Similarly, locative verbs like **lie, stand, sit** may express states: **the Nile lie in Africa** means  $\lambda t$ .the place of the Nile is in Africa throughout  $t$ . Finally, states are expressed by stage-level nouns: **Sue be a student** means  $\lambda t$ .Sue is a student throughout  $t$ .

The conclusion is: the semantic analysis of states requires moments. States are what (Klein, 1994) calls 1-state predicates; each instance of such a predicate is a pair consisting of one individual and *one* moment. States are projected to time intervals via an additional operation **THR**. The latter point is not standard. In what follows I will ignore this insight and deal with states as if they were sets of intervals *simpliciter*, but a proper analysis requires the said decomposition.

### 3.2. *Achievements*

Achievements are predicates that describe sudden changes: **realize, discover, spot, find.**

Intuitively, an achievement is true of a point of change between a  $\neg\phi$ -state to a  $\phi$ -state.

(8) Achievements

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where ----- =  $\neg\phi$ , ++++ =  $\phi$ , | = the point of change

The non-trivial question is how such points of changes can be described by lexical contents.

Consider the VP **Franzis find her wallet**. Intuitively this is true at a moment  $m$  if Franzis sees her wallet at  $m$  and she doesn't see it immediately before  $m$ . In a theory that works with discrete time we have no problem to analyse this. Let us denote the predecessor of a moment  $m$   $\text{pred}(m)$ . The VP mentioned therefore means  $\lambda m.$ Franzis sees her wallet at  $m$  & she doesn't see it at  $\text{pred}(m)$ . The corresponding lexical entry would be this:

(9)  $\llbracket \mathbf{find}_{m(e(t))} \rrbracket = \lambda m \in M. \lambda x. \lambda y. y$  doesn't see  $x$  at  $\text{pred}(m)$  &  $y$  sees  $x$  at  $m$ .

The first conjunct of the truth-condition should better be a presupposition, a refinement we neglect. So the semantics of achievements seems to require discrete time.

(Dowty, 1979) gives an interval semantics for achievements, which requires a discrete time structure as well. His formalisation uses the BECOME-operator, but to make the point, we can formulate the lexical entry of **find** directly:

(10) Dowty's discrete interval semantics for achievements

$\llbracket \mathbf{find}_{i(e(t))} \rrbracket = \lambda t \in T. \lambda x. \lambda y. y$  doesn't see  $x$  at  $\text{lb}(t)$  &  $y$  sees  $x$  at  $\text{rb}(t)$

&  $\neg(\exists t' \subset t) y$  doesn't see  $x$  at  $\text{lb}(t')$  &  $y$  sees  $x$  at  $\text{rb}(t')$

The reader should convince himself that any interval  $t$  that satisfies these conditions must consist of two moments.<sup>7</sup>

But we are not forced to the conclusion that the semantics for achievements requires discrete time. Here is a semantics for achievements that works for a continuous time structure, as far as I can see:

(11) Achievements for continuous time

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<sup>7</sup> Suppose  $t$  did consist of two short abutting subintervals  $t_1$  and  $t_2$ , each consisting of more than one point.  $t_1$  is a  $\neg\phi$ -interval,  $t_2$  is a  $\phi$ -interval. But then we could find two shorter subintervals  $t, t'$  fulfilling the conditions and so on down to two neighbouring moments. So  $t$  has the form  $[m_1, m_2]$  with  $m_1$  immediately before  $m_2$ . But in a continuum such an interval cannot exist because reals don't have successors.

$$\llbracket \mathbf{find}_{m(e(et))} \rrbracket = \lambda m \in M. \lambda x. \lambda y. (\exists n_1 < m)[y \text{ doesn't see } x \text{ at } n_1 \ \& \ (\forall n_2)[n_1 < n_2 < m \rightarrow y \text{ doesn't see } x \text{ at } n_2]] \ \& \ y \text{ sees } x \text{ at } m$$

This means that the  $\neg\phi$ -interval approaches the  $\phi$ -point from the left without ever reaching it. So the question of the predecessor or successor doesn't arise. The conclusion is that the semantics for achievements requires the existence of time points, but time may nevertheless be continuous. Let me say again that the first conjunct in the definition should better be a presupposition. As for states, I will simplify in the following by treating achievements as if their time argument were a short interval.

### 3.3. Accomplishments

The property of Accomplishments accepted by everyone is:

(12) “Quantization”

$P_{it}$  is an *Achievement/Accomplishment* if for any time  $t$ : If  $P(t)$  and  $t'$  is a proper subinterval of  $t$ , then  $\neg P(t')$ -

The term “quantization” comes from (Krifka, 1989), but the condition originates with Vendler. If achievements are only defined for moments, the property of quantization follows trivially. An *accomplishment*  $P$  is quantized and only defined for genuine intervals, i.e., intervals that contain more than one point. As in example consider the VP **Max polish his car**. This denotes the set of intervals  $t$  such that Max starts polishing his car at the beginning of  $t$ , he works on his car throughout  $t$  and the car is clean at the end of  $t$ . So the meaning of **polish** is something like this:

$$(13) \quad \llbracket \mathbf{polish}_{i(e(et))} \rrbracket = \lambda t. \lambda x. \lambda y. y \text{ works on } x \text{ at } t \text{ such that } x \text{ is clean at } rb(t) \\ = \lambda t. \lambda x. \lambda y. y \text{ polishes } x \text{ at } t$$

In this particular case the property of being an accomplishment is determined by the lexical semantics of the verb. As has been mentioned earlier, this is not always so. The VP **John walk** is what is called an *activity* (see next section). But the VP **John walk from the Post Office to the station** is an accomplishment. The example is from (Dowty, 1979), who presents many other examples of this sort.

### 3.4. Activities

An activity is very similar to a state. An activity property has the subinterval property down to some small intervals that are necessary to make the predicate true. The classical examples are



**John walk** or **John waltz**: the activity of walking requires to take at least one step, and that of waltzing requires at least three steps. So these predicates cannot be true of moments. Activities are cumulative (or summative):

(14) Cumulativity of activities

If  $P_{it}$  is activity and  $P$  holds of two abutting intervals  $t_1$  and  $t_2$ , then  $P$  holds of  $t_1 \cup t_2$ .

Since activities are almost states, they should be treated in a similar way, i.e., they should be defined for minimal intervals, which are extended by an appropriate version of the covert operator  $THR$  to larger interval.

(15)  $[[ \text{walk}_{i(et)} ]]$  =  $\lambda t. \lambda x. x$  walks at  $t$

Each  $t$  in this set contains only one minimal walk of the subject. But we will be sloppy by assuming that these walking intervals can be very long.

### 3.5. *How many time arguments?*

An inspection of the lexical entries for the different kinds of predicates given in the last section reveals that I assumed one time argument for each predicate. Now, achievements and accomplishments are what (Klein, 1994) calls two state verbs. He holds the view that these verbs must have two time arguments; recently he claims that two may not even be sufficient; cf. (Klein, 2000, Klein, 2002). It is true that achievements and accomplishments speak about two times (the time before the change and the time after the change for achievements, the action time and the target time for accomplishments). But in each case the other time can be recovered from the unique time the predicate speaks about. At least, this is the usual assumption present in most work about tense semantics. However, one time argument is not sufficient for every purpose. For instance, the stative (or adjectival) passive seems to project the “target state” on the time axis. The VP **the car be polished** can mean “the car is clean as a result of a polishing”. Clearly this is true of times that are immediately after a polishing; the car still has to be clean at those times. Suppose then that the lexical entry for **polish** is the following:

(16) **polish** as a 2-state verb: type  $t(m(e(et)))$

$[[ \text{polish} ]]$  =  $\lambda m. \lambda t. \lambda x. \lambda y. y$  polishes  $x$  at  $t$  and  $m = rb(t)$

The “stativizer” that forms the adjectival passive would then be an operation that “absorbs” the event time and the agent and project the target time and the patient. Apart from details,

this account goes back to (Kratzer, 2000):

(17) The stativizer ST: type  $(m(i(e(et))))(m(et))$

$$[[ \mathbf{ST} ]] = \lambda R_{m(i(e(et)))}. \lambda m. \lambda x. (\exists t)(\exists y) R(m)(t)(x)(y)$$

Thus the adjectival passive VP has the LF  $\lambda m. \mathbf{the\ car\ [ST\ polished]}(m)$  and means  $\lambda m. (\exists t)(\exists y)[y \text{ polishes } x \text{ at } t \text{ and } m = rb(t)]$ . When the verb is in the active, we need a different operation that “absorbs” the target time and projects the event time:

(18) The eventizer EV, type  $(m(i(e(et))))(i(e(et)))$

$$[[ \mathbf{EV} ]] = \lambda R_{m(i(e(et)))}. \lambda t. \lambda x. \lambda y. (\exists m) R(m)(t)(x)(y)$$

So the VP **Max polish his car** has the LF  $\lambda t. \mathbf{Max\ [EV\ polish]}(t) \mathbf{his\ car}$  and means  $\lambda t. (\exists m)[m = rb(t) \ \& \ \text{John polishes his car at } t]$ . This is exactly what we had under our 1-state treatment of **polish**.

The outcome of this discussion is that it is correct that verbs ultimately may have more than one time argument, but when it comes to the VP, where the subject and the object have been plugged in, only one argument remains. The other argument is bound by one of the two operations. In order to not complicate the picture, we will assume that verbs have only one time argument.

The question that still has to be answered is this: Which argument of the verb (or other predicates) is the time argument? Is it the first or is it the last? I know of no convincing evidence for deciding this question. In this article, I will assume that the time argument is the first argument of the predicate.

The summary of this discussion is that states are sets of intervals, but stative verbs are sets of moments. We come to the states via the operation **THR**. These have the subinterval property. Achievements are sets of moments, which we identify with very short intervals. Accomplishments are sets of time intervals. Activities are somehow in between accomplishments and states. They have the subinterval property, but only down to some granularity.

#### 4. LF

In this section I introduce an extensional typed language L that will serve for the representation of logical forms (LFs). The intensional extension is introduced in section 11.2.

The *types* of L are: *e* (entities), *i* (time intervals), *m* (moments), *s* (worlds) and *t* (truth-values). The functional types are generated by the following rule: if *a* and *b* are types, then

$(ab)$  is a type. Outermost bracket are usually omitted.

The syntax of  $L$  is based on a lexicon of expressions belonging to some type in the style of the examples already given. Furthermore, we have infinitely many variables for any type (often written as numbers with type indices or as traces with numbers). Finally we have the following syntactic rules:

(19) Syntax of  $L$

1. If  $\alpha$  is a lexical entry or a variable of type  $a$ , then  $\alpha$  is an expression of type  $a$ .  
 (“Lexicon”)
2. If  $\alpha$  is an expression of type  $(ab)$  and  $\beta$  is an expression of type  $a$ , then  $[\alpha \beta]$  is an expression of type  $b$ . (“functor-argument”)
3. If  $\alpha$  and  $\beta$  are expressions of type  $(at)$ , then  $[\alpha\beta]$  is an expression of type  $(at)$ .  
 (“predicate modification”)
4. If  $\alpha$  is an expression of type  $a$  and  $x$  is a variable of type  $b$ , then  $[\lambda x\alpha]$  is an expression of type  $(ba)$ . (“abstraction”)

The interpretation of the language is based on a model  $\mathfrak{M} = (M, T, E, \{0,1\}, s^*, F)$ , where  $M$  is the set of moments,  $T$  is the set of time intervals based on  $M$ ,  $E$  is the set of entities,  $\{0,1\}$  is the set of truth-values, and  $s^*$  is the speech time. (A more inclusive model should include the set  $W$  of possible worlds.)  $F$  is a function that interprets the lexicon with appropriate meanings. To do this, we need a system of semantic domains  $D_a$  for each type  $a$ . We define:  $D_m = M$ ,  $D_i = T$ ,  $D_e = E$ ,  $D_t = \{0,1\}$ , and  $D_{(ab)}$  = the (possibly partial) functions from  $D_a$  into  $D_b$ . A condition for the interpretation of the lexicon is that  $F(\alpha) \in D_a$  if  $\alpha$  is a lexicon entry of type  $a$ .

We now define the function  $\llbracket \cdot \rrbracket^{\mathfrak{M},g}$  that interprets each expression of  $L$ . The function depends on the model  $\mathfrak{M}$  and a variable assignment  $g$ .

(20) Interpretation of  $L$

1. a. If  $\alpha$  is a lexical entry of type  $a$ , then  $\llbracket \alpha \rrbracket^{\mathfrak{M},g} = F(\alpha)$ . (“Lexicon”)
- b. If  $x$  is a variable of type  $a$ , then  $\llbracket x \rrbracket^{\mathfrak{M},g} = g(x)$  (“Variable”)

- 
2. If  $\alpha$  is of type  $ab$  and  $\beta$  is of type  $a$ , then  $\llbracket [\alpha\beta] \rrbracket^{20,g} = \llbracket \alpha \rrbracket^{20,g} (\llbracket \beta \rrbracket^{20,g})$   
 (“Functional Application”, FA)
3. If  $\alpha$  and  $\beta$  are of type  $at$ , then  $\llbracket [\alpha\beta] \rrbracket^{20,g} = \lambda x_a. \llbracket \alpha \rrbracket^{20,g}(x) \& \llbracket \beta \rrbracket^{20,g}(x)$ .  
 (“Predicate Modification”, PM)
4. If  $x$  is a variable of type  $a$  and  $\alpha$  is an expression of type  $b$ , then  
 $\llbracket [\lambda x \alpha] \rrbracket^{20,g} = \lambda u \in D_a. \llbracket \alpha \rrbracket^{20,g[x/u]}$ .  
 (“Abstraction”,  $\lambda$ )

$g[x/u]$  is defined like  $g$  with the (possible) exception that  $g[x/u](x) = u$ . As a special case of PM we will assume that  $\alpha$  and  $\beta$  are of type  $t$ . Then  $\llbracket [\alpha\beta] \rrbracket^{20,g} = 1$  iff  $\llbracket \alpha \rrbracket^{20,g} = 1 = \llbracket \beta \rrbracket^{20,g}$ .

## 5. TEMPORAL STRUCTURE OF SIMPLE SENTENCES

We start with the sentences:

- (21) a. John called.  
 b. Mary is happy.

There is a long tradition in Generative Grammar that the structure of finite sentences is  $[_{TP} T VP]$ . In other words, a Tense is the head of the sentence. At S-structure, the subject moves to  $[Spec,TP]$  for case reasons, and the main verb moves to T. We ignore these movements for semantics. We will assume the following two Tenses for English:

- (22) Tenses  
 a. Present, type  $i$ :  $F(\mathbf{N}) = s^*$ .  
 b. Past, type  $i(it,t)$ :  $F(\mathbf{P}) = \lambda t. \lambda P_{it}. (\exists t') [t' < t \& P(t')]$

Semantic tenses are covert, i.e. they are not pronounced. The semantic past  $\mathbf{P}$  is a relative tense, it shifts the local evaluation time backwards. We assume that the argument of  $\mathbf{P}$  is always  $\mathbf{N}$  in matrix clauses. This warrants a deictic interpretation. (In subordinate clauses,  $\mathbf{P}$  can have a time variable  $t$  as argument that is bound by a higher tense or locally bound by a  $\lambda$ -operator. Matrix Past is represented as  $[\mathbf{P} \mathbf{N}]$ . This is quantifier and requires an argument of type  $it$ . How is this possible? Here are the lexical entries for **John** and **called**:

- (23) a.  $F(\mathbf{John}_e) = \text{John}$   
 b.  $F(\mathbf{called}_{i(et)}) = \lambda t. \lambda x. x \text{ calls at } t$ .

Note that **called** has a tenseless semantics. In other words the morphology of the verb is not directly reflected in its semantics. I will take up the morphology/semantics interface in the

next section. The first argument of the verb is a time argument. At deep structure this is filled with a semantically empty pronoun PRO, which has no meaning and no type. Therefore it has to be moved for type reasons creating a  $\lambda$ -abstract of type *it*. At LF PRO is deleted. This is the PRO-theory of (Heim and Kratzer, 1998). Here is the derivation of the LF for sentence (21a); the movement of the subject to [Spec,TP] and the movement of the verb to T is ignored.

- (21) DS:  $[_{TP} [_T P N] [_{VP} John [called PRO]]]$   
 PRO-movement (with subsequent PRO deletion)  
 LF:  $[_{TP} [_T P N] \overline{PRO} \lambda_1 [_{VP} John [called t_1]]]$   
 $= (\exists t < s^*) \text{ John calls at } t$

The LF is transparent, i.e. interpretable. The reader may compute for herself that it has the interpretation indicated. The method of calculation is entirely standard. We have to use Functional Application and the abstraction rule.

The analysis of sentence (21b) requires the introduction of the auxiliary **be**, which has an entirely trivial semantics: it simply passes the matrix tense to the adjective: adjectives have a time argument but they aren't finite forms.

- (24) The temporal auxiliary **be**: type  $i(it,t)$   
 $F(\mathbf{is}) = \lambda t. \lambda P_{it}. P(t)$

Here is the derivation of the LF for the sentence:

- (25) DS:  $[_{TP} P N [_{VP} [V \text{ is } PRO] [_{AP} Mary \text{ happy } PRO ]]]$   
 PRO movement (with subsequent PRO deletion)  
 LF:  $[_{TP} P N \lambda_1 [_{VP} [V \mathbf{is} t_1] \lambda_2 [_{AP} \mathbf{Mary \ happy} t_2]]]$   
 $= (\exists t < s^*) \text{ Mary is happy at } t$

Again, the reader may convince himself that the LF has the meaning indicated.

The Perfect and the Pluperfect require the auxiliary **have**, which has the same meaning as the semantic Past **P**.

- (26) **have/had**: type  $i(it,t)$   
 $\lambda t. \lambda P_{it}. (\exists t') [t' < t \ \& \ P(t')]$

Thus the analysis of *John had called* is the following:

- (27)  $[_{it,t} P N] [\lambda_1 [[\mathbf{had} t_1] [\lambda_2 [John [called t_2]]]]]$

$$= (\exists t_1)[t_1 < s^* \ \& \ (\exists t_2 < t_1)[\text{John calls at } t_2]]$$

There is something idiosyncratic with the English Present Perfect, which requires a special meaning. The standard account for **have** under semantic Present is that the auxiliary expresses an “extended now” XN; cf. (Dowty, 1979: chap. 7). This is an interval whose right bound is  $s^*$ :

(28) XN-Perfect

$$\llbracket \text{has} \rrbracket = \lambda t. \lambda P_{it}. (\exists t') [t \text{ is a final subinterval of } t' \ \& \ P(t')]$$

The future auxiliary **will** is the mirror image of **have**:

(29) **will**: type  $i(it, t)$

$$\lambda t. \lambda P_{it}. (\exists t') [t' > t \ \& \ P(t')]$$

(30) John will call.

$$N [\lambda_1 \llbracket \text{will } t_1 \rrbracket [\lambda_2 \llbracket \text{John [call } t_2 \rrbracket \rrbracket]]]$$

$$= (\exists t') [t' > s^* \ \& \ \text{John calls at } t']$$

The English Progressive is a modal operator and requires the introduction of the world argument into the semantics. I give a hint what the analysis of *Max was polishing his car* will be. The auxiliary **was** expresses Dowty’s (1979) PROG-operator. In other words, the auxiliary **be** is ambiguous between a tense transmitter and the Progressive. The LF will be this:

(31)  $[_{TP} P N_1 [_{VP} \text{was}(@, t_1) \lambda_2 \lambda w [_{VP} \text{Max polishing}(w, t_2) \text{his car}]]]$

$$= (\exists t < s^*) (\forall w) [ @ R_t w \rightarrow (\exists t') [t \subseteq t' \ \& \ \text{rb}(t') > \text{rb}(t) \ \& \ \text{Max polishes his car in } w \text{ at } t' ] ]$$

@ is the actual world and  $@ R_t w'$  means that  $w$  is accessible to @ at time  $t$ .  $R$  must be an appropriate accessibility relation, more or less what Dowty calls the “inertia” worlds. These have a common past with the real world but might diverge from the real world in the future but should be compatible with our expectations at time  $t$ . There is quite an amount of literature to the Progressive. Notice that the progressive verb form **polishing** has exactly the same meaning as other forms of the verb. PROG is not expressed by this verb but by the auxiliary **was**.

Some remarks on the literature are in order. Semantic Past is decomposed into a relative tense (like the Perfect) and the deictic Present (or a time variable). As far as I know this decomposition has been proposed for the first time in (Heim, 1997). It is used in

(Kusumoto, 1999). Our semantic tense is indefinite, i.e. **P** is a restricted existential quantifier. In many places of the literature we find a relative Past that quantifies over an implicit time parameter on which the interpretation depends:  $\llbracket \mathbf{P} \alpha \rrbracket^t = (\exists t' < t) \llbracket \alpha \rrbracket^{t'}$ ; see for instance (Montague, 1973). Most authors (e.g. (Ogihara, 1996), (Kusumoto, 1999)) attribute this semantics to (Prior, 1967). I was not able to verify this; Prior's work is entirely axiomatic and mostly concerned with the reconstruction of Diodorian modality. But the interpretation seems to be in the spirit of Prior. **N** is the “now” of (Kamp, 1971). The great advantage of a decomposed Past is that it can correctly deal with back shifted readings in subordinate constructions. Note that other languages have different interpretation for the Present. In Japanese and German the Present can express a non-Past, i.e.  $\lambda t. \lambda P_{it}. (\exists t') [-t' < t \ \& \ P(t')]$  or some related, even more complicated versions using overlap with the speech time; see (Abusch, 1994), (Klein, 1994), (Musan, 2002) among others for different variants. We have seen that **have** may have different meanings, either it is synonymous with **P** or it expresses an XN. (Musan, 2002) defends the view that the German Perfect gives us a time that is either before a reference time  $t$  or gives us an XN in the limiting case, i.e. Perfect =  $\lambda t. \lambda P. (\exists t') [t' < t$  or  $t'$  is a final subinterval of  $t \ \& \ P(t')]$ . The auxiliary system proposed in this section is compositional. This is a controversial matter.<sup>8</sup> For a survey and discussion of the different proposals that have been made, see (Kratzer, 1998).

## 6. SYNTAX AND MORPHOLOGY

I am assuming a feature theory in the style of (Zeijlstra, 2004). There are two sorts of features, interpretable ones [iF] and uninterpretable ones [uF]. The interpretable features originate with certain logical operators, e.g. Negation or Tense. They reflect the meanings of these operators. The uninterpretable features are carried by other expressions that do not have the said meaning but may morphologically expose the meaning. An interpretable feature may check an uninterpretable one under agreement. If one i-feature checks more than one u-feature, we have “Multiple-Agree”.

In English, finite verb forms have uninterpretable temporal features. Present forms of a verb have the feature [uN] “uninterpretable Present/Now”. The semantic Present **N** has the

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<sup>8</sup>For instance, clausal participles require covert operators (*die vor Jahrhunderten erbaute Burg* ‘the before centuries built castle’, *die seit Jahrhunderten zerstörte Burg* ‘the since centuries destroyed castle’). Some researchers think that the semantic Past is contained in the participle and auxiliaries are semantically void.

feature [iN] “interpretable Present/Now”. Past forms of a verb have the feature [uP] “uninterpretable Past”. The semantic Past tense **P** has the feature [iP].

(32) Some verb forms with spell out:

Present: **call/calls** [uN]

Past: **called** [uP]

Past Participle: **called** (no temporal feature)

Infinitive: **call** (no temporal feature)

Meaning of all these:  $\lambda t.\lambda x.x$  calls at time  $t$

We will assume the following conventions for the transmission of temporal features under binding.

(33) Feature transmission under semantic binding.

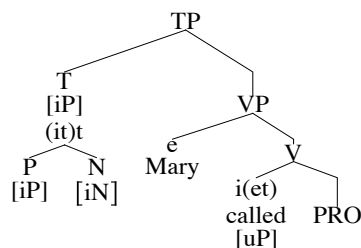
A semantic tense **P** or **N** transmits a feature [uP]/[uN] to the time variable it binds. If the variable is an argument of a tensed verb form, the feature has to agree with the tense feature of the verb.

The idea that features may be transmitted under semantic binding is due to Irene Heim; see e.g. (Heim, 1994b), (Heim, 2005).

We assume the conventions for semantic binding out-lined in (Heim and Kratzer, 1998). In particular, a phrase or operator  $\alpha$  may bind a variable via a  $\lambda$ -operator. To generate the necessary  $\lambda$ -operators, we assume that cases-less argument positions are filled with the semantically empty pronoun PRO, which must be moved (“QR-ed”) thus creating a  $\lambda$ -abstract. Being semantically empty, PRO is deleted after movement. Case positions may be filled with the semantically empty operator WH, the relative pronoun. It is moved and creates a  $\lambda$ -abstract as well. Here is the analysis of a simple sentence.

(34) Mary called.

Deep structure (=DS)



(The subject **Mary** is moved to [Spec,TP] for case reasons at SS. This will be ignored.) The



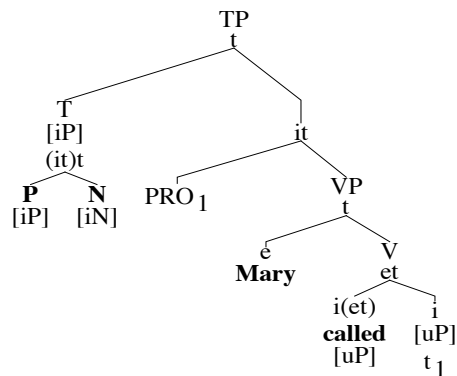
tree assumes the following convention for feature percolation:

- (35) Percolation of tense features
  - a. Features percolate along the head line.
  - b. The feature of a temporal variable either agrees with the inherent feature of the head or it is transmitted to the head (and percolates to the phrase).

Since the semantic Past is the head of the semantic tense [P N], the feature [iP] percolates to the phrase [P N].

The tree is not interpretable because PRO has no meaning and no type. Therefore, PRO has to be QR-ed (PRO-movement) creating a  $\lambda$ -bound trace. This creates the interpretable tree:

(36) The LF



PRO<sub>1</sub> is the  $\lambda$ -operator  $\lambda_1$ . By means of this operator, [P N] transmits the feature [uP] to the bound variable t<sub>1</sub>. [uP] agrees with the internal feature [uP] of **called**. Thus the finite verb always makes visible the semantic Tense of the sentence. Wolfgang Klein addresses this phenomenon as FIN-time in recent papers.

A note to the literature. This system of feature transmission is very similar to that in (Kratzer, 1998). Kratzer claims that PRO (her zero tense  $\emptyset_i$ ) has no temporal feature in the lexicon. The features are copied from the antecedent under binding. In (von Stechow, 2003) I claimed that PRO comes into life with a temporal feature because it is needed at PF for the morphology. The present approach is neutral to the question. PRO might come into the syntax without or with a temporal feature. The essential point is that the feature is checked under binding via agreement, presumably at LF. After checking the features may be deleted in agreement with Chomsky's views of the behaviour of features.

## 7. TEMPORAL ADVERBIALS

In this section we consider the scope interaction of frame setting temporal adverbials like the one in the following sentence.

(37) Mary called on my birthday.

The simplest account of these temporal adverbials/PPs has them of type *it*. The adverbs are combined with the VP by Predicate Modification.

(38)  $[[\text{on my birthday}]] = \lambda t.t \text{ is on my birthday}$

The following is the analysis we find in (Heim, 1997).

(39) Mary called on my birthday.

$[P\ N] \lambda_1 [[\text{Mary called } t_1] [t_1 \text{ on my birthday}]]$   
 $= (\exists t_1)[t_1 < s^* \ \& \ t_1 \text{ is on my birthday} \ \& \ \text{Mary calls at } t_1]$

Here are the relevant lexical entries:

(40) Temporal Ps, type *i(it)*

a.  $F(\text{on/in}) = \lambda t.\lambda t'.t' \subseteq t$   
 b.  $F(\text{at}) = \lambda t.\lambda t'.\lambda P_{it}.t' = t$

**on** and **in** mean the same, but **on** is restricted to days, weekends and perhaps few other dates. **in** is reserved to larger time spans (e.g. *in 1975*). In many cases, **on** is covert, for instance with deictic dates such as **yesterday**, **today**, **tomorrow**.

(41) Deictic dates: type *i*

$F(\text{yesterday}) = \text{the day before the day that contains } s^*$ .

So the temporal adverb *yesterday* is represented as **ON yesterday** with covert **on**. I am using capitals for phonetically covert stuff. This semantics explains at least partially what (Klein, 2002) calls the Present Perfect Puzzle, i.e. the fact that the present perfect doesn't combine with adverbs that denote a past time.

(42) \*John has called yesterday.

$N \lambda t_1 \text{ has}(t_1) \lambda_2 [[\text{PartP John called}(t_2)] [t_2 \text{ on yesterday}]]$   
 $= (\exists t)[\text{the final point of } t \text{ is } s^* \ \& \ \text{John calls in } t \ \& \ t \subseteq \text{yesterday}]$

**ON yesterday** modifies the XN-interval, which gives rise to an inconsistency because an interval that contains the speech time cannot be on yesterday. Note that the participle phrase **John called** has to be related to the perfect time by means of the Perfective operator **PF**; which is defined in (50). The analysis ignores this, but the truth-condition takes care of this

by locating John's call *in* the XN. The logical syntax has to make sure that temporal adverbs cannot be combined with VPs that are below PF. Note that the feature [uN] of **has** makes sure that the XN-auxiliary is always embedded under the semantic Present.

Time names like **six o'clock** are embedded under the preposition **at**, which expresses identity. As (Klein, 1994) and many other authors have noticed, temporal PPs may create an ambiguity when they scopally interact with the perfect auxiliary:

(43) Mary had left at six.

a. **[P N]  $\lambda t$  [[have (t)  $\lambda t$  Mary left(t)] [t at six]]**

$(\exists t < s^*) t$  at 6 o'clock &  $(\exists t' < t)$  Mary leaves at  $t'$

b. **[P N]  $\lambda t$  [have (t)]  $\lambda t$  [Mary left(t) [t at six]]**

$(\exists t < s^*)(\exists t' < t) t'$  at 6 o'clock & Mary leaves at  $t'$

(43a) is a Past-time (reference) time modification: the leaving is before six. (43b) is a Past-Past-time (event time) modification, the leaving is at six.

An interesting problem, which was discovered by (Ogihara, 1994), arises when the object of a temporal preposition is a quantifier:

(44) John worked on every Sunday.

a. **P N  $\lambda t$  every Sunday  $\lambda t'$  t on  $t'$  John worked(t)**

$(\exists t < s^*)(\forall t')[\text{Sunday}(t') \rightarrow t \text{ on } t' \ \& \ \text{John works at } t]$

b. **every Sunday  $\lambda t'$  P N  $\lambda t$  t on  $t'$  John worked(t)**

$(\forall t')[\text{Sunday}(t') \rightarrow (\exists t < s^*) [t \text{ on } t' \ \& \ \text{John works at } t]]$

The analysis assumes that **every Sunday** is a temporal quantifier of type  $(it)t$  and means  $\lambda P_{it}.(\forall t)[\text{Sunday}(t) \rightarrow P(t)]$ . Neither of the two readings is correct. Reading (44a) entails that there is a past time that is on every Sunday. Reading (44b) entails that every Sunday contains a time before the speech time. What we want is the following reading:

(45)  $(\forall t')[\text{Sunday}(t') \ \& \ \underline{t' < s^*} \rightarrow (\exists t < s^*) [t \text{ on } t' \ \& \ \text{John works at } t]]$

In other words, the Sundays we quantify over must be restricted to the past. Where does this restriction come from? We know that quantifiers come with domain restrictions. Assuming a framework in the style of (von Stechow, 1994), we assume that the temporal determiner **every** takes a variable  $C$  of type  $it$  as its first argument. The proper representation of *every Sunday* would then be **every<sub>C</sub> Sunday** with the meaning  $\lambda P.(\forall t)[\text{Sunday}(t) \ \& \ g(C)(t) \rightarrow P(t)]$ . Assume that  $g(C) = \{t \mid t < s^*\}$ . Take now the LF in (44b) with the so restricted

determiner. This will give you the meaning in (45).

## 8. TENSES AS REFERRING TERMS?

The semantics of the Past assumed here is indefinite, i.e. **P** is an existential quantifier, which shifts the local evaluation time backwards. (Partee, 1973) argued that such a theory cannot be correct. Tenses are more like pronouns. They refer to definite times. Her crucial example is this:

- (46) I didn't turn off the stove.  
 $\neq$  a.  $(\exists t < s^*) \neg I \text{ turn off the stove at } t$   
 $\neq$  b.  $\neg(\exists t < s^*) I \text{ turn off the stove at } t$

The first interpretation is obtained from an LF in which Past ( i.e. **P N**) has wide scope with respect to the negation  $\neg$ . The second reading is expressed by an LF in which the negation out-scopes the semantic Past. The first reading is trivial and the second is too strong. Partee's conclusion is that the semantic Past must be something like a pronoun that refers to a past time the speaker has in mind. Partee didn't make this precise. A reasonable way to implement the idea is due to (Heim, 1994a):

- (47) Referential Past: type ii.  
 $[[ \text{PAST} ]]^{s^*} = \lambda t:t < s^*.t$

PAST is a function that takes a time as an argument and is only defined if the time is before  $s^*$ . If this is so, the value of the function is that time. The argument of PAST is given by a temporal variable. It is tempting to symbolize Partee's sentence as:

- (48) NOT I turn off (PAST( $t_5$ )) the stove  
 $= \neg I \text{ turn off the stove at } g(t_5), \text{ where } g(t_5) < s^*$

$t_5$  would then denote a particular time in the past, which the speaker has in mind. As realized by Partee herself later on this cannot be the whole story, however. The action of turning of the stove takes a very short time, and it is virtually impossible that the speaker can refer to that time. The speaker might have in mind a longer time stretch, say the time from 11 to 12 AM, the period before her leaving. But this means that the meaning of **turn\_off** cannot be the function  $[\lambda t.\lambda x.\lambda y.y \text{ turns off } x \text{ at } t]$ . It rather has to be  $[\lambda t.\lambda x.\lambda y.y \text{ turns off } x \text{ in } t]$ . But what does it mean that the action of turning off the stove occurs in the interval  $t$ ? It means that it occurs *at some subinterval of t*. So a lexical entry of the verb that is compatible with Partee's account must be this:

- (49) An accomplishment for Partee  
 $[[\text{turn\_off}]] = \lambda t. \lambda x. \lambda y. (\exists t') [t' \subseteq t \ \& \ y \text{ turns off } x \text{ at } t]$

While this gives the correct truth-condition for Partee's sentence, this is presumably not a prosperous route to go down. To mention one difficulty: it seems hard to give a semantics for the Progressive **turning off** on the basis of this lexical semantics. In fact, this semantics should better be decomposed into an **at**-semantics for the verb plus a semantic Perfective operator, i.e. an operation that localises the event time within some other time (normally the "reference time" or "topic time").

- (50) The Perfective, type  $t((it)t)$  (Krifka, 1986), (Klein, 1994)  
 $[[\text{PF}]] = \lambda t. \lambda P_{it}. (\exists t') t' \subseteq t \ \& \ P(t')$

The Partee sentence would then better be analysed as:

- (51) **PAST( $t_5$ )  $\lambda t$   $\neg$  PF( $t$ )  $\lambda t$  I turn\_off( $t$ ) the stove**  
 $= \neg(\exists t \subseteq t_5) \text{ I turn off the stove at } t, \text{ where } t_5 < s^*$

An approach of this kind has become rather popular (see e.g. (Abusch, 1994), (Heim, 1994a), (Kratzer, 1998)), but a closer inspection shows that it undermines the arguments of Partee against an indefinite analysis of time. By  $\lambda$ -conversion, the LF in (51) is equivalent with

- (52)  **$\neg$  PF(PAST( $t_5$ ))  $\lambda t$  I turn\_off( $t$ ) the stove**

If we can make sure that the indefinite Past tense means precisely **PF(PAST( $t_5$ ))**, i.e.  $(\exists t \subseteq t_5)$ , then the indefinite tense theory is restored and the originally rejected LF (46b) proves to be the (basically) correct one.

## 9. RESTRICTING TENSE

Our indefinite Past is an existential quantifier and comes with a domain restriction. So the refined lexical entry is this:

- (53) Contextually restricted Past: type  $(it, i(it,t))^9$   
 $[[\text{P}]] = \lambda C. \lambda t. \lambda Q. (\exists t') [C(t') \ \& \ t' < s^* \ \& \ Q(t')]$

The analysis of the Partee sentence is then:

- (54) **not [P<sub>C</sub> N]  $\lambda t$ . I [turn-off( $t$ ) the stove]**

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<sup>9</sup> Restrictions of this kind have been introduced in (Musan, 2002).

If  $g(C) = \{t \mid t \subseteq [11 \text{ a.m.}, 12 \text{ a.m.}]\}$ , the LF means:

$\neg(\exists t < s^*) t \subseteq [11 \text{ a.m.}, 12 \text{ a.m.}] \& \text{ I turn off the stove at } t$

This is almost the same truth-condition as before. The only difference is that the past time quantified over is presupposed in the first account but introduced by an existential quantifier in the second approach. The second approach contains a “definite part” as well, viz. the times in C. The first approach contains an indefinite part as well, but it is contained in the lexical entry. Note that we don’t need the Perfective operator to obtain the correct meaning.

The domain restriction is useful for other purposes as well. I has been noted by many scholars that the event time of a Future Perfect construction should be after the speech time:

(55) John will have left at six.

We obtain the correct result if we assume the following pragmatic principle:

(56) An embedded tense or temporal auxiliary adds the “content” of the next super ordinate tense to its restriction provided the super ordinate tense is compatible with the tense in question.

The “content” of a Past are the times before  $s^*$ , the content of a future are the times after  $s^*$ , and so on. We have to add domain variables for the lexical entries of temporal auxiliaries, of course. The analysis of (55) is then the following:

(57) **N**  $\lambda t$  **WILL**<sub>C1</sub>(t)  $\lambda t$  **t at 6** **have**<sub>C2</sub>(t)  $\lambda t$  **john left**(t)  
 $g(C1) = \{t \mid t \text{ a time}\}$   
 $g(C2) = \{t \mid t > s^*\}$   
 $= (\exists t)[t > s^* \& t = 6 \& (\exists t')[t' > s^* \& t' < t \& \text{John leaves at } t']]$

## 10. SCOPE INTERACTIONS WITH TENSE

Negation and quantifiers interact scopally with Tense. As we have seen, the negation usually takes wide scope. This makes correct predictions for the following sentence:

(58) It didn’t rain today.  
**not P N**  $\lambda t$  **rain**(t) **t ON today**  
 $= \neg(\exists t < s^*) t \subseteq \text{today} \& \text{it rains at } t$

Note that it is impossible to analyse this sentence correctly by means of the original Partee approach, i.e., the approach without the Perfective operator. The best approximation to the meaning using the Perfective is the following:

(59) **PAST(t<sub>5</sub>) λt ¬PF(t) λt rain(t) t ON today**

= t<sub>5</sub> ⊆ today & ¬(∃t ⊆ t<sub>5</sub>) it rains at t, t<sub>5</sub> < s\*

As it stands the reading is too weak, because t<sub>5</sub> might be very short. Intuitively, however, the sentence means that the time in today that precedes s\* is without rain. In order to get that reading we need a pragmatic principle saying that the reference time has to be as long as possible. (Musan, 2002: ch. 3) assumes such a principle. Another feature of this analysis is that the temporal adverb **ON today** has to be in the scope of the Perfective operator. Our short discussion of the Present Perfect ended with the conclusion that this option should be excluded. The indefinite analysis in (58) covers the facts without additional assumptions and seems preferable.

As noticed by (Heim, 1997), quantifiers tend to take wide scope with respect to semantic tense as well. This accounts for some facts observed in (Cresswell, 1979):

(60) John polished every boot.

‘John polish a boot’ is an accomplishment that can only be predicated of an interval. The point of the example is that we need a different past interval for each boot because John cannot polish each boot at the same time. We obtain the desired reading by scoping **every boot** over the semantic Past:

(61) **every boot λx P N λt John polished(t) x**

= (∀x)[boot(x) → (∃t < s\*)[John polishes x at t]]

Again, an analysis in Partee’s original approach is not possible. A referential theory of Tense needs the Perfective operator in order to achieve temporal co-variation for the quantifier. So the indefinite semantics for the Past has some advantages over the referential theory.

## 11. SUBORDINATE TENSE

A touchstone for the adequacy of the semantics for tense is the behaviour of tenses in subordinate constructions. The literature discusses three different types of constructions: (i) Tense in relative clauses; (ii) tense in complement clauses, i.e., tense under attitudes; (iii) tense in adjunct clauses, notably **before/after**-clauses. In languages like Russian or Japanese, the facts are relatively easy to analyse. Unfortunately, this is not so for English, where each of these constructions requires a different strategy.

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### 11.1. *Tense in Relative Clauses*

The most interesting observation, due to (Ogihara, 1989), concerns the behaviour of relatives under Future.

- (62) Mary will buy a fish that is alive.  
 a.  $ST = MT$  (simultaneous)  
 b.  $ST = s^*$  (deictic)
- (63) Mary will buy a fish that has been alive.  
 $ST < MT$  (shifted)  
 $ST < s^*$  (deictic, Perfect)
- (64) Mary will buy a fish that was alive  
 $ST < s^*$  (deictic)  
 ?  $ST < MT$  (shifted).

I am using the following abbreviations:  $ST$  = the event time of the subordinate clause,  $MT$  = the event time of the matrix clause. The important observation is that the simultaneous reading in (62), i.e., the fish is alive at the time of the buying, which is in the future, is expressed by a present form. Since this event is in the future, the semantic tense correlated to this morphology cannot be a semantic Present because the latter denotes the speech time.

The facts of English can be described by the following assumption:

- (65) The semantic tense of the relative clause is obligatorily bound, here by a higher tense.<sup>10</sup>

A semantic tense is bound if the semantic Present **N**, which is part of it, is replaced by a temporal pronoun **Tpro**, which is obligatorily bound. Details aside, this is the account given in (Kusumoto, 1999).<sup>11</sup>

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<sup>10</sup> When a relative clause is in the scope of an attitude, the semantic tense may also be bound by the attitude predicate (see below).

<sup>11</sup> Kusumoto uses a distinguished temporal variable  $t^*$  for our **N**. In matrix sentences,  $t^*$  denotes  $s^*$ . In subordinate contexts,  $t^*$  may be bound. The temporal argument of the semantic Past is a variable **past<sub>i</sub>** which denotes only if  $g(\mathbf{past}_i) < s^*$ , the semantics of (Kratzer, 1998). Basically, this is the meaning of referential Past. Since this variable is always bound in Kusumoto's system, this complication doesn't buy anything, as far as I can see. Therefore, it



Here are the analyses of sentence (62):

$$(66) \quad \mathbf{N} \lambda_1 \mathbf{will}(t_1) \lambda_2 \mathbf{M. buy}(t_2) \mathbf{a fish WH}_3 \mathbf{Tpro}_2 \lambda_4 \mathbf{is}(t_4) \lambda_5 \mathbf{x}_3 \mathbf{alive}(t_5)$$

$$\begin{array}{cccccc} \text{iN} & \text{uN} & \text{uN} & \text{uN} & \text{uN} & \text{uN} \\ = (\exists t > s^*)(\exists x)[\text{fish}(x) \ \& \ \underline{\text{alive}}(x,t) \ \& \ \text{buy}(\text{Mary},x,t)] \end{array}$$

This is the simultaneous reading. **Tpro** is bound by **will** but it gets its uN-feature from the matrix **N** via a binding chain. This feature is ultimately realised by the finite verb **is**. Here we have the first non-trivial case of feature transmission under semantic binding. It is worth to notice that tenseless forms like the infinitive (or adjectives and the past participle) transmit temporal features under binding.

A note to the analysis of the relative clause. It is formed by moving the semantically empty relative pronoun **WH** to [Spec,C] thereby creating a  $\lambda$ -abstract, represented as [**WH**<sub>1</sub>  $\alpha$ ]. The relative clause is combined with the head noun **fish** by Predicate Modification. The LF ignores the fact that the object “a fish that is alive” has to be QR-ed for type reasons. All this is standard.

The deictic reading of (62) requires binding of **Tpro** to the matrix **N**:

$$(67) \quad \mathbf{N} \lambda_1 \mathbf{will}(t_1) \lambda_2 \mathbf{M. buy}(t_2) \mathbf{a fish WH}_3 \mathbf{Tpro}_1 \lambda_4 \mathbf{is}(t_4) \lambda_5 \mathbf{x}_3 \mathbf{alive}(t_5)$$

$$= (\exists t > s^*)(\exists x)[\text{fish}(x) \ \& \ \underline{\text{alive}}(x,s^*) \ \& \ \text{buy}(\text{Mary},x,t)]$$

The semantics is different, but the feature transmission is as before. I leave it to the reader to provide the analyses for the sentences in (64) and (65).

The grammatical status of the shifted reading of (65) is doubtful. (Abusch, 1996) and (Kratzer, 1998) accept it. Their example is *Next month I will answer every e-mail that arrived*. The analysis of these sentences has a semantic Past of the form **P(Tpro<sub>1</sub>)** in the relative clause, where **Tpro<sub>1</sub>** is bound to the matrix **N**. If we want to block such constructions, we have to stipulate that the semantic tense in relative clauses is always an obligatorily bound **Tpro** and nothing else.

Our account of feature transmission makes the correct prediction that the Present in the following relative clause can only have a deictic interpretation.

$$(68) \quad \text{Mary talked to a boy who is crying.}$$

$$\text{deictic} \checkmark, \text{ simultaneous}^*$$

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is not adopted to the present approach.

As before we obtain the deictic reading by binding the **Tpro** to the matrix **N**. We could bind **Tpro** to the matrix **Past**, but then the transmitted temporal feature would be [uP], which would be in conflict with the inherent feature [uN] of the auxiliary **is**.

For **Past** under **Past** constructions, the literature assumes three readings:

- (69) Mary talked to a boy who was crying.
- a.  $ST = NT$  (simultaneous)
  - b.  $ST < MT$  (backward shifted)
  - c.  $ST > MT$  (independent, forward shifted)

The forward shifted reading is prominent in the following sentence, which is due to Ogihara:

- (70) Hillary married a man who became the president.

The simultaneous reading is obtained by having a **Tpro** (and no **P**) in the relative clause, where **Tpro** is bound to the matrix **Past**. The backward shifted reading is obtained by a semantic **Past** in the relative, which is bound to the matrix **Past**, and the independent reading has an embedded **Past** bound to **N**. The latter reading is a deictic reading, and the forward shifting is a purely pragmatic thing. Obviously, this interpretation could deal with the two remaining cases in (69) as well. So **Past** under **Past** doesn't give us convincing data that require bound tense in the relative clause. We could have a deictic **Past** in all these cases. But attitudes will give us data that can only be dealt with within the binding approach:

- (71) John thought that he would buy a fish that was still alive. (Ogihara)

The event time of the relative clause certainly isn't before the speech time. Thus a referential analysis is impossible. Let us look to tense under attitudes then.

## 11.2. *Tense under Attitudes*

To deal with attitudes we have to enrich our semantic framework in a way that it can deal with attitudes. For this purpose we introduce an intensional  $\lambda$ -language. "Intensional" means that expressions of type  $a$  express meanings of type  $(sa)$ , i.e.,  $a$ -intensions. Recall that  $s$  is the type of possible worlds  $W$ ,  $D_{sa}$  is the set of (partial) functions from  $W$  into  $D_a$ . In particular, each lexical entry will denote an intension. So the former lexical entries have to be revised to take care of the world argument. Here are some examples:

- (72) Some revised lexical entries:

- a.  $F(\mathbf{John}_e) = \lambda w. \text{John}$   
 b.  $F(\mathbf{called}_{i(et)}) = \lambda w. \lambda t. \lambda x. x \text{ calls in } w \text{ at } t$ .  
 c.  $F(\mathbf{N}_i) = \lambda w. s^*$   
 d.  $F(\mathbf{P}_{i(it,t)}) = \lambda w. \lambda t. \lambda P_{it}. (\exists t' < t) P(t')$

Apart from the interpretation of the language  $\llbracket \cdot \rrbracket^{20,g}$  is as before. The only innovation is Heim & Kratzer's rule Intensional Functional Application (IFA).

(11-73) Recursive definition of the interpretation function  $\llbracket \cdot \rrbracket_{F,g}$

1. Let  $\alpha$  be a lexical entry of type  $a$ . Then  $\llbracket \alpha \rrbracket^{20,g} = F(\alpha)$ .
2. Let  $x$  be a variable of type  $a$ . Then  $\llbracket x \rrbracket^{20,g} = \lambda w. g(x)$ ,  $g(x)$  in  $D_a$ .
3. **FA**: Let  $\alpha$  have type  $b$  and daughters  $\beta$  of type  $ab$  and  $\gamma$  of type  $a$ .

$$\llbracket \alpha \rrbracket^{20,g} = \llbracket \beta \rrbracket^{20,g}(w)(\llbracket \gamma \rrbracket^{20,g}(w))$$

4. **IFA**: Let  $\alpha$  have type  $b$  and daughters  $\beta$  of type  $(sa)b$  and  $\gamma$  of type  $a$ .

$$\llbracket \alpha \rrbracket^{20,g} = \lambda w. \llbracket \beta \rrbracket^{20,g}(w)(\llbracket \gamma \rrbracket^{20,g})$$

5. **PM**: Let  $\alpha$  have type  $a$  and daughters  $\beta$  and  $\gamma$  of the same type.

$$\llbracket \alpha \rrbracket^{20,g} = \lambda w. \lambda x. \llbracket \beta \rrbracket^{20,g}(w) \& \llbracket \gamma \rrbracket^{20,g}(w)$$

6. **Abstraction**: Let  $x$  be a variable of type  $a$  and let  $\alpha$  be an expression of type  $b$ .

$$\llbracket \lambda x \alpha \rrbracket^{20,g} = \lambda w. \lambda u \in D_a. \llbracket \alpha \rrbracket^{20,g[x/u]}(w)$$

The standard way of defining complements of predicates of attitudes is to say that they are simply propositions, i.e. sets of worlds. For instance, the sentence *It is raining* (Progressive ignored) would mean  $[\lambda w. \text{it rains in } w \text{ at } s^*]$ . A straight forward semantics of attitudes in the style of (Hintikka, 1969) would be this:

(74) *believe*, type  $(st)(i,et)$

$$F(\mathbf{believe}) = \lambda w. \lambda p_{st}. \lambda t. \lambda x. (\forall w')[w' \text{ is compatible with everything } x \text{ believes of } w \text{ in } w \text{ at time } t \rightarrow p(w')]$$

*John believes it is raining* could then be analysed as:

(75)  $\mathbf{N} \lambda t \mathbf{John} \mathbf{believes}(t) [\mathbf{N} \lambda t \mathbf{is}(t) \lambda t \mathbf{raining}(t)]$  (to be revised)

$$= \lambda w. (\forall w')[w' \text{ is compatible with everything John believes of } w \text{ in } w \text{ at time } s^* \rightarrow \text{it is raining in } w' \text{ at } s^*]$$

Since the sentential complement is of type  $t$  whereas **believes** requires a complement of type  $st$ , we have to use IFA for the semantic composition. The example embeds a tensed

proposition with deictic Present. Now it has been known at least since (Prior, 1967) that tense under attitudes cannot have a deictic interpretation. The sentence *John believed that it was raining* it used to report a belief of John that he would have worded as: “It is raining”. In other words, an embedded Past is used to express a “subjective now”. In order to express this, the embedded Tense has to be bound. Using the strategy we know from the interpretation of relative clauses, we may assume a **Tpro** in the embedded clause and bind it to the matrix Past:

- (76) John believed it was raining (to be revised)  
**P N  $\lambda_1$  John believed( $t_1$ ) Tpro $_1$   $\lambda_2$  was( $t_2$ )  $\lambda_3$  raining( $t_3$ )**  
 $= \lambda w.(\exists t_1 < s^*)$  John believes in  $w$  at  $t_1$   $\lambda w'.it$  is raining in  $w'$  at  $t_1$

This analysis correctly accounts for the licensing of the embedded past tense morphology, because the matrix Past transmits its [uP]-feature to **was** via the binding chain. And the semantics looks reasonable. An anaphoric of this kind has been proposed by (Gennari, 2003) among others.

It has been know for a long time that this cannot be the whole story ((von Stechow, 1984), (Abusch, 1994), (Heim, 1994a), (von Stechow, 1995) among others). The analysis assumes that the subject knows precisely the time at which he is, but we are mostly wrong about the time. Consider the following sentence still assuming the anaphoric approach:

- (77) At 5 o' clock Mary thought it was 6 o'clock.  
**P N  $\lambda_1$   $t_1$  at 5 o' clock Mary thought( $t_1$ ) Tpro $_1$   $\lambda_2$  was( $t_2$ )  $\lambda_3$   $t_3$  at 6 o'clock**  
 $= \lambda w.(\exists t_1 < s^*)$   $t_1 = 5$  o'clock & Mary thinks in  $w$  at  $t_1$   $\lambda w'.t_1 = 6$  o'clock.

According to this analysis, the content of Mary's belief is the proposition that 5 o'clock is 6 o'clock, a blatant contradiction. Intuitively, however, there is nothing wrong with Mary's belief, she simply believes that the time at which she is located is 6 o'clock.

A solution of the problem following (Lewis, 1979) is this: despite the morphological appearance, the complement of the attitude predicate is not a temporally independent proposition of type  $st$  but a temporally dependent proposition of type  $s(it)$ , i.e. a property of times. In other words, the clausal complement of the sentence in (77) is the proposition that the time  $t_1$  is 6 o'clock but the property of being at 6 o'clock. We obtain this property by abstracting **Tpro $_1$**  away. The semantics of the verb of attitudes has to be revised accordingly.

- (78) *believe*, type  $(s(it))(i,et)$  (style of (Lewis, 1979))





- a. John will enter the room before Mary leaves.
- b. John will enter the room after Mary has left.
- c. John will enter the room after Mary leaves.
- d. \*John will enter the room after Mary will leave.
- e. \*John will enter the room before Mary will leave.

If the main clause contains a Past, we invariably find a Past in the adjunct clause.

(85) Mary left before/after John arrived.

Let us first ask what *before* and *after* mean. Sentences like the following suggest that the prepositions simply denote the relation of temporal precedence (<) and succession (>) respectively.

(86) Mary arrived after/before 6.

Sticking again to the initial extensional framework, the semantics is simply this:

(87) *before/after* type i(it)  
 $F(\text{before/after}) = \lambda t. \lambda t'. t' </> t$

The LFs of the sentences in (86) are therefore:

(88) **[P N]  $\lambda t$  t after/before 6  $\lambda t$  Mary arrived(t)**  
 $= (\exists t)[t < s^* \ \& \ t > /< 6 \text{ o'clock} \ \& \ \text{Mary arrives at } t]$

The temporal adverbial is composed with the VP via Predicate Modification.

Next consider the temporal adjunct clauses in (86). (Heim, 1997) proposes that the construction is analysed along the lines of the following paraphrase:

(89) Mary left before/after the time at which John arrived.

Here the complement is of type i, which is appropriate for the object position of the temporal preposition. Now this paraphrase is not sufficient because John might have arrived at many times. We therefore follow (Beaver and Condoravdi, 2003) and proceed along the following paraphrase:

(90) Mary left before/after the earliest time at which John arrived.<sup>12</sup>

“time at which John arrived” is a relative clause of type it. The information “the earliest” is

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<sup>12</sup> With *after* the operator *the latest* might be more appropriate in some cases. The analysis would be entirely parallel for that choice.

provided by the following coercion operator:

- (91) EARLIEST: type (it)<sub>i</sub>  
 $[[\text{EARLIEST}]] = \lambda P_{it}.$  the earliest time  $t$  such that  $P(t)$ .  
 $=$  the  $t$ , such that  $P(t) \ \& \ (\forall t')[P(t') \rightarrow t < t']$

The analysis of (90) is this:

- (92) **P N  $\lambda_1$  [[Mary left( $t_1$ )] [ $t_1$  before EARL WH<sub>2</sub> P N  $\lambda_3$   $t_3$  AT  $t_2$  John arrived( $t_3$ )]]**  
 $= (\exists t_1 < s^*)$  M. leaves at  $t_1$  &  $t_1 <$  the earliest  $t_2$  s.t.  $(\exists t_3 < s^*)$   $t_3 = t_2$  & J. arrives at  $t_3$   
 $= (\exists t_1 < s^*)$  M. leaves at  $t_1$  &  $t_1 <$  the earliest  $t_2 < s^*$  s.t. J. arrives at  $t_2$

In addition to the EARLIEST-operator the relative construction is covert, which you may not like. But the construction is semantically transparent and involves no new principles of composition.<sup>13</sup> In (92) we assumed a deictic tense in the complement. We know that this is not possible in the case of Future constructions. We therefore apply the SOT-rule that has been introduced in the last section, i.e., we delete Present under Present:

- (93) The interpretation of **before/after** clauses requires the application of the SOT-rule, i.e. dense deletion under c-command.<sup>14</sup>

A plain deletion won't do because the Tense occurs directly under a WH-operator, which requires a sentence of type  $t$ . After tense deletion, we have something of type  $it$ , and the WH-operator would convert it into something of type  $i(it)$ , not a good argument for the EARLIEST-operator. Therefore we rather replace the Tense by a covert existential quantifier  $\exists$  of type  $(it)t$ , which means  $\lambda P_{it}.$  $(\exists t)P(t)$ . Here is the analysis of (84a):

<sup>13</sup> A further motivation for this analysis is that it provides a straightforward account of the sentences observed in (Geis, 1970). The sentence *I saw Mary in New York before she claimed that she would arrive* has two readings depending on the origin of the temporal relative pronoun WH. The LFs for the temporal adjuncts are these: (i) **t before EARL WH<sub>1</sub>  $\exists$   $\lambda_2$   $t_2$  AT  $t_1$  she claimed( $t_2$ )  $\lambda_3$  would( $t_3$ )  $\lambda_4$  she arrive( $t_4$ );** (ii) **t before EARL WH<sub>1</sub>  $\exists$   $\lambda_2$  she claimed( $t_2$ )  $\lambda_3$  would( $t_3$ )  $\lambda_4$   $t_4$  AT  $t_1$  she arrive( $t_4$ ).** The interesting and intuitively prevailing reading is that with the second adjunct: Mary claimed that she would arrive on Sunday, but I met her on Saturday.

<sup>14</sup> Note that auxiliaries don't qualify as semantic tenses. **Have** is never deleted.



- (94)  $\mathbf{N} \lambda_1 \mathbf{will}(t_1) \lambda_2 \mathbf{John\ enter}(t_2) t_2 \mathbf{before/after\ EARL\ WH}_3 \mathbf{N} \exists \lambda_4 t_4 \mathbf{AT\ } t_3 \mathbf{Mary\ leaves}(t_4)$   
 $= (\exists t_2 > s^*) \text{ John enters the room at } t_2 \text{ \& } t_2 >/< \text{ the earliest } t_3 \text{ s.t. Mary leaves at } t_3.$

This is the correct reading, provided the **EARLIEST**-operator quantifies over future times. To achieve this, we have to assume a domain restriction **C** for the operator that copies the semantic content of the next higher Tense, here **will**. After this refinement, we can explain the oddness of the sentences (84d/e): the earliest future time at which Mary *will* leave is a time right after the speech time. This creates nonsense or at least confusion.

Note that we have to license the present of the embedded verb before the application of Tense Deletion.

To summarize this section: we can analyse the facts by means of Ogihara's SOT-rule with successive insertion of an existential quantifier. The result is a configuration that is different from the two preceding ones: the construction is not anaphoric nor does it contain a zero tense. The evaluation of the construction shows that the temporal variable of the verb is ultimately bound by the EARLIEST-operator.

Here are some remarks to the literature. The standard treatment of **after/before**-clauses is due to (Anscombe, 1964). Anscombe treats the prepositions as generalised quantifiers mapping two temporal properties to a truth-value. There is no uniform semantics. **after** means  $\lambda P_{it}.\lambda Q_{it}.\langle \exists t \rangle \langle \exists t' \rangle [P(t) \ \& \ Q(t') \ \& \ t > t']$ , and **before** means  $\lambda P_{it}.\lambda Q_{it}.\langle \exists t \rangle [P(t) \ \& \ (\forall t') [Q(t') \rightarrow t < t']]$ . Among other things, this approach has the problem of integrating semantic tense, a question Anscombe is not concerned with. Many authors, e.g. (Heinämäki, 1974), (Ogihara, 1996), (Kusumoto, 1999) use variants of this semantics and either have no semantic tense or admit that they face difficulty in integrating it. The first approaches that use the simple unified semantics of the prepositions are (von Stechow, 2002) and (Beaver and Condoravdi, 2003). Most ingredients in the present account are found in (Heim, 1997).

## 12. CONCLUSION

English has the Tenses, Present (**N**), Past (**P**), and the temporal pronouns **Tpro** and **PRO**. In addition we have the temporal auxiliaries **have** and **will**. The temporal morphology of finite verbs is licensed under semantic binding, which requires an open quantification over time in the syntax, i.e., verbs must have temporal variables. The treatment of tense in subordinate constructions requires different strategies. (i) Tense in relative clauses can be treated anaphorically; the Tense in the relative clause is an obligatorily bound **Tpro**. (ii) The Tense in

complements of attitudes is PRO, which is moved for type reasons and creates a  $\lambda$ -abstract, i.e. complements of attitudes are tenseless. (iii) **after**- and **before**-clauses are treated either deictically or as tenseless; the latter requires a slightly different strategy from the treatment of attitudes: we delete a tense and replace it by  $\exists_{i(it)}$ . In this article I have treated some non-trivial constructions of English but by no means all the constructions I am aware of. I am convinced that the system is general enough to be able to be applied to other constructions as well.

### 13. APPENDIX

Here is the most trivial example to illustrate how the truth-values of LFs are computed. The calculation is given for convincing the reader that the system is entirely formal.

$[[[TP [T P N] PRO \lambda_1 [VP John [called t_1]]]]]^g$	LF for <i>John called</i>
iff $[[P N]]^g ([[ \lambda_1 [VP John [called t_1]] ] ]^g)$	FA
iff $(\exists t < s^*) [[ \lambda_1 [VP John [called t_1]] ] ]^g (t)$	FA and Lexicon
iff $(\exists t < s^*) \lambda t'. [[ [VP John [called t_1]] ] ]^{g[1/t']} (t)$	Abstraction
iff $(\exists t < s^*) [[ [VP John [called t_1]] ] ]^{g[1/t]}$	$\lambda$ -conversion
iff $(\exists t < s^*) F(\mathbf{called})(g[1/t](t_1))(F(\mathbf{John}))$	FA and Lexicon
iff $(\exists t < s^*) F(\mathbf{called})(t)(F(\mathbf{John}))$	Definition of $g[1/t](t_1)$
iff $(\exists t < s^*) \text{John calls at } t$	FA, Lexicon, $\lambda$ -conversion

The last line stands for the truth-value 1. More complicated examples are treated analogously and may require very long computations.

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