Aspects of *Until*

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Abstract

A formal analysis of *until* within the framework of Dynamic Event Semantics is presented. It derives the frame points of *until*-clauses from their aspectual class.

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1 Introduction

1.1 Some Data

Any analysis of *until* in English must explain the following two phenomena. First, there is an aspectual restriction on the sentence in the main clause. Only sentences are admitted that are aspectually either of type activity or state, (1a). Sentences of type accomplishment or achievement are excluded, witness (1b).

(1) a. John ran/was ill until Mary arrived.

b. *John ate an apple/reached the station until Mary arrived.

If the accomplishment expression in the main clause is negated, (2a), or progressivized, (2b), the sentence becomes acceptable (similarly for an achievement expression). This change in acceptability is expected because both negation and the progressive trigger an aspectual shift. Expressions of type accomplishment or achievement are turned into expressions of type state.[1]

[1] The same holds for expressions of type activity. They too are turned into stative expressions as the test with *at*-adverbials shows.

(2) a. John didn't eat an apple until Mary arrived.

b. John was eating an apple until Mary arrived.

c. John ate apples until Mary arrived.

Example (2c) shows that the aspectual properties of the whole sentence and not only that of the underlying verb do matter. As the test *eat apples *in ten minutes/for ten minutes* shows, *eat apples* is an expression of sort activity and not of sort accomplishment.

The second phenomenon has to do with the dependence of the interpretation of an *until*-sentence on the aspectual properties of the subordinate clause.

(3) a. John was jobless until Mary built a house.

b. John watched TV until Mary ran.

In the case of (3a) John must have been without a job either at least up to the beginning of Mary's building a house or to the end point of her building the house. For instance, in the first situation John could participate in building the house whereas in the second situation he could have got a job after the house was finished because Mary started running a business in it and needed co-workers. For an accomplishment expression the time specified by the *until*-clause up to which the event denoted in the main clause must at least go on is therefore not uniquely determined. If a speaker wants to uniquely determine this *frame point*[2] he has to use aspectual verbs that directly refer to the beginning or the end of an event or the perfect, e.g. by using *began to build*, *finished building*, or *had built* in (3a). On the other hand, for (3b) with an activity expression in the subordinate clause only the first of the two interpretations is available: John must have been watching TV at least up to the beginning of Mary's running.

The difficulty for an analysis of *until* is that this dependence of the frame point on the aspectual class of the *until*-clause cannot be explained in purely temporal terms. The run time of each event has both a beginning and an end point, irrespective of the aspectual properties of the clause that is used to refer to it. It is even possible to refer to one event with two sentences that belong to distinct aspectual classes. For instance, *John walked* and *John walked to the store* can both be used to refer to a particular walk of John. Yet, the first sentence is of type activity whereas the second is of type accomplishment.

It is important to note that the event denoted by the main clause can go on beyond the frame point, as example (4) illustrates.

(4) John didn't talk until the lawyer arrived. He even continued his silence after the lawyer had arrived.

a. John did not work at noon.

b. John was working at noon.

Both sentences admit a non-inchoative, non-habitual reading. For a detailed analysis of constructions of the form *not ... until* where *until* is taken in its adverbial use, see de Swart (1996).

[2] Called so with reference to Hamann (1989), according to whom temporal clauses "frame" the reference time of the main clause.

The end-of-process interpretation is a *conversational implicature* at best. According to Hamann (1989) it can be derived from the "be informative" maxim, since the *until*-sentence tells nothing about the time after the frame point. A more suggestive explanation is that on the pragmatic level *until* often has a *causal* connotation, especially if the main clause is negated. The event referred to in the subordinate clause is interpreted to cause the state or process described in the main clause to stop. But such a causal relationship is not part of the semantics of *until* itself.

1.2 *Until* in Logic and Programming

A standard formalization of *until* in the guise of temporal logic is the following first-order definition (e.g. Goldblatt, 1992, van Benthem, 1996):

$$(5) \qquad P \,\mathrm{until}\, Q \;=\; \{x \mid \exists y(x < y \,\wedge\, Qy \,\wedge\, \forall z(x \leq z < y \rightarrow Pz))\}\,.^{3}$$

Here, $<$ is the relation of temporal precedence between time points and the schematic letters 'P' and 'Q' stand for predicates denoting time points. (P and Q are also called "*propositions*".) Because of this restriction to stative expressions, definition (5) obviously falls short as an approach to cover the semantics of *until* in natural language as revealed in section 1.1.

Another formalized occurrence of *until*, well known to everybody familiar with imperative programming languages, is the **repeat-until** construct. Its definition in terms of Propositional Dynamic Logic is as follows (e.g. Kozen & Tiuryn, 1990):[4]

$$(6) \qquad \mathbf{repeat}\, A \,\mathbf{until}\, Q \;=\; A \circ {*}(?\neg Q \circ A) \circ ?Q\,,$$

where Q is a proposition and A is a *program*, or, talking syntax, the schematic letters 'Q' and 'A' stand respectively for monadic and dyadic predicates. With respect to the application we have in mind we interpret "programs" as binary relations between time points. Since we assume in addition the set of time points to be linearly ordered, this framework shows some affinity to Dynamic Modal Logic (see van Benthem, 1996) restricted to linear frames. A translation of (6) into first order logic plus ancestral is possible by using the first order definitions of the test and composition operators '?' and '$\circ$'.[5]

Dynamic Logic is appealing because it overcomes the restriction to stative expressions, that is, to monadic predicates over times. The formal language is "*exogenous*" with respect to transitions – they are explicitly mentioned – in contrast to temporal logic, which is "*endogenous*" in this respect (cf. Kozen & Tiuryn, 1990). Nevertheless, several drawbacks are to notice. A first inconvenience concerns the interpretation of programs as relations between time points. What is to say about two time points besides temporal

[3] Some readers may prefer '$\lambda x(\ldots x \ldots)$' over '$\{x \mid \ldots x \ldots\}$'. This makes no difference because our notation for abstraction can be read syntactically; see Quine (1969) for background.

[4] We prefer consistent prefix notation for unary operators and assume them to have smallest possible scope.

[5] $?P = \{xy \mid x = y \wedge Px\}$, $A \circ B = \{xy \mid \exists z(Axz \wedge Bzy)\}$. The *ancestral* $*R$ of a binary relation R is $\bigcup\{R^n \mid n \geq 0\}$.

order? Obviously, that something happened between them, or, to be more specific, that something happened starting at the one point and ending at the other. It seems reasonable to make this reference to events explicit, that is, to make the logic exogenous with respect to events. For this purpose we replace programs by event types.

In order to allow tracing of the changes brought about by events we assume two functions α and ω such that $\alpha\text{‘}x$ and $\omega\text{‘}x$ are respectively the beginning and the end point of an event x.[6] (6) can then be rendered into

$$(7) \qquad \textbf{repeat}\, E\, \textbf{until}\, Q \;=\; (E \wedge \omega{:}Q) \vee {}^{\star}(E \wedge \omega{:}\neg Q) \bullet (E \wedge \omega{:}Q)\,,$$

where the operators ‘:’, ‘$\bullet$’ and ‘$\star$’ are defined as follows. $R{:}Q$ is the *inverse image* (the “*Peirce product*”) of a set Q by a binary relation R.[7] Sequencing ‘$\bullet$’ and iteration ‘$\star$’ make recourse to a functional ternary *composition relation* C between events. ‘Czxy’ is to be read as ‘z consists of x followed by y’. The relation between the event sequencing and their beginning and end is captured by postulate

$$(8) \qquad \mathrm{C}zxy \;\rightarrow\; \alpha\text{‘}z = \alpha\text{‘}x \wedge \omega\text{‘}z = \omega\text{‘}y \wedge \omega\text{‘}x = \alpha\text{‘}y\,.$$

A further restriction on C ensures associativity of the sequencing operator ‘$\bullet$’:[8]

$$E \bullet F \;=\; \mathrm{C}\text{“}(E \times F) \;=\; \{z \mid \exists xy(\mathrm{C}zxy \wedge Ex \wedge Fy)\}\,.^{9}$$

The definition of ${}^{\star}F$ now simply is $*(\mathrm{C}\text{“}F)\text{“}F$. Each event of type ${}^{\star}F$ consists of a finite number of successive subevents of type F. Expression (6) differs from (7) in appearance because there is by definition at least one such subevent.[10]

Although (7) overcomes the restriction to stative expressions criticized in (5), it seems to be orthogonal to the requirements for an analysis of the data presented in section 1.1. The **until** clause describes a state whereas the “main clause” – the “body” of the **repeat-until** construct – denotes an event, i.e. a “dynamic” entity. According to section 1.1, on the other hand, the main clause of the *until*-sentence is restricted to state and activity descriptions. A closer look, however, reveals that (7) is quite adequate as a logical analysis of examples like (9), where the main clause has an *iterative* reading and the subordinate clause describes a state.

(9) Mary knocked at the door until John was awake.

[6] Here, functions are functional relations. Holding with Quine (1969) against the tide, ‘Fxy’ has to be read as ‘x is the F of y’ (and not the other way around). ‘$F\text{‘}y$’ stands for ‘$\iota x(Fxy)$’.

[7] $R{:}Q \;=\; \{y \mid \exists x(Rxy \wedge Qx)\}\,.$

[8] $\exists x(\mathrm{C}zxy \wedge \mathrm{C}xuv) \leftrightarrow \exists w(\mathrm{C}zuw \wedge \mathrm{C}wvy)$.

[9] $R\text{“}Q \;=\; \{x_1 \dots x_m \mid \exists y_1 \dots y_n(Rx_1 \dots x_m y_1 \dots y_n \wedge Qy_1 \dots y_n)\}$ (Image of Q by R).

[10] There is a strong resemblance to Arrow Logic, Amsterdam style; cf. van Benthem, 1996. The operations $\bullet$, $\alpha{:}$, $\omega{:}$, and $\star$ obey e.g. the following identities, which follow from the definitions.

$$E \bullet F \wedge \omega{:}Q \;=\; E \bullet (F \wedge \omega{:}Q)\,,$$
$$E \bullet (\alpha{:}Q \wedge F) \;=\; (E \wedge \omega{:}Q) \bullet F\,,$$
$${}^{\star}(E \wedge \omega{:}\neg Q) \bullet (E \wedge \omega{:}Q) \;=\; E \bullet {}^{\star}(\alpha{:}\neg Q \wedge E) \wedge \omega{:}Q\,.$$

2 Event Dynamics and Aspectual Theory

2.1 Dynamic Event Semantics

It is common nowadays in natural language semantics to adopt an approach, often dubbed as "neodavidsonian", which assumes non-stative verbs to make reference to actions and events. We go beyond this in that we make excessive recourse to the time course of events, their evolution in time, and the changes of states brought about by them. Besides allowing for an aspectual classification of verbs (section 2.2), this will prove to be the adequate level of analysis in order to capture the frame point of *until* clauses as well as its variability (section 4). Our framework might be referred to as *Dynamic Event Semantics* (Naumann, 1997a,b).

The basic idea can be rephrased in terms of the notion of *change*, which comprises at least two perspectives that are complementary to but interwoven with each other. On the one hand, a change is an event; on the other hand, it is a novel state which is brought about by an event, that is, the *result* of a change in the first sense. The second aspect of a change, changes as transformations of states, is captured in Propositional Dynamic Logic where programs are interpreted as binary relations between time points. The disadvantage of this approach, as emphasized in section 1.2, is that the first aspect is not captured at all. Changes as transformations are derived objects, i.e. relations between time points. They are not treated as "first class citizens" of the domain of entities. This latter perspective is captured in event semantics (e.g. Krifka, 1992), where events are individual entities.

Event semantics reifies events and describes their mereological structure by algebraic laws. The relation to the temporal domain is given through the temporal extension of events, by which temporal precedence and overlap of events are definable. What is *not* taken into account is the inherent temporal direction of events – presumably because of an unreflected transfer of ideas from mereological theories of plurals and mass nouns. Dynamic Event Semantics claims to overcome this restriction by uniting the two perspectives of the notion of change mentioned above.

Referring to time points and events is linguistically justified. Indubitable predicates of the latter are nominalizations of non-stative verbs. In the following, event predicates (event types) might be thought of as *sentence radicals* in the sense of Galton (1984), that is, as "tenseless sentence frames". We assume time points to be linearly ordered by $<$ and two functions α and ω as in section 1.2. A further assumption is that everything takes time, i.e. $\alpha`x < \omega`x$ for each event x.[11] To keep things simple, *intervals* (*periods*) are treated as (convex) sets of time points.[12]

Section 1.2 introduced a predicate 'C' to express that events consist of consecutive subevents. An event x is called an *initial segment* of an event y, in symbols, $x \lhd y$, iff there is an event z such that $\mathrm{C}xyz$. In the following this relation will typically be used to state that all initial segments of an event x are of the same type E. One way to express this is that x is of type $\neg(\neg E \bullet \top)$, with $\top$ as the most general type. Since this is the only use of sequencing (besides the analysis of iterates given above) more restricted operators

[11] The reasons are, besides experience of life, more on the technical side than a matter of principle.

[12] For a more appropriate alternative see e.g. Kamp & Reyle, 1993.

are convenient: '$\Diamond^{\downarrow}E$' for '$E \bullet \top$', i.e. for '$\{x \mid \exists y(y \lhd x \wedge Ey)\}$', and '$\Box^{\downarrow}E$' for '$\neg\Diamond^{\downarrow}\neg E$'. Note that since $\alpha`x < \omega`x$, (8) implies that if $x \lhd y$ then $x \neq y$.

Events are supposed to have an "*active argument*" by which we mean the entity that undergoes the change brought about by the event at hand. In the case of running events it is the runner, in the case of eating events the thing eaten. Let us assume an operation Θ which takes event types to functional relations between entities and events, the former being objects that take part in the latter. Suppose further that ΘExy iff y is of type E and x is the active argument of y with respect to event type E.[13] The change the object undergoes is captured by an additional time-dependent property. More about that in section 2.2.

The status of *states* notoriously calls for reflection.[14] Confining ourselves to copula sentences we could say that the entity denoted by the subject serves as the "active" argument (better to be called "stative" now) of the state described. The relevant property of the argument, which in this case is *constant* in time, is explicitly given in the state description by the predicative adjective (or noun). If a copula sentence describes John as being ill then John is the active argument and being ill the relevant property. The state type (the predicate) at question is not *being ill* but *someone's being ill*. To coin a slogan, a state is always a state of someone or something.[15] In the following we refer to states and events both as *eventualities*.

2.2 Aspectual Classification

In this section we sketch a theory of the aspectual distinction between accomplishments and activities. Related classifications are *telicity* vs. *atelicity* and *terminativity* vs. *durativity*. The first class of verbs is often characterized to have an "intrinsic culmination point". Obviously, this term is intensionally loaded since the culmination point is identical to the terminal point, and terminal points are nothing specific to accomplishments. The phenomenon at question cannot be characterized in purely temporal terms, to repeat an insight of section 1.1.

According to Krifka (1992), telic event types are characterized by (10).[16]

(10) $\forall xy(Ex \wedge Ey \wedge x \sqsubseteq y \rightarrow x = y)$ (Quantized Reference)

This property, however, is both too strong and too weak to characterize accomplishments (Naumann, 1997a). It is too weak because every final segment of a walk to the store is a walk to the very same store.[17] It is stronger than necessary since we can do with

[13] It would not be adequate to assume such a relation *independent* of the type of the event as one cannot exclude misleading contingencies. For an event token can satisfy more than one event predicate, that is, can be of more than one type, and different descriptions may pick out different active arguments. Thus, to be the active argument of an event is not an extensional but a conceptual question, that is, a question of description.

[14] It is indisputable that states can be referred to: *Mary was happy. As usual, this state didn't last long.*

[15] Note that an approach which treats states as time intervals would not be appropriate because two people could by accident always be ill at the same time (one interval is enough), which would make it impossible to determine the "active" argument of that state.

[16] '$x \sqsubseteq y$' means that x is a temporal segment of y.

[17] This is admitted by Krifka (1992).

initial segments. An appropriate characterization of accomplishments therefore is given by condition (11a), which prevents initial segments to be of the same type as the complete event.

(11) a. $E \subseteq \neg\Diamond^{\downarrow}E\,,\quad$ that is, $\forall xy(Ex \wedge y \lhd x \rightarrow \neg Ey)\,.$

b. $E \subseteq \Box^{\downarrow}E\,,\quad$ that is, $\forall xy(Ex \wedge y \lhd x \rightarrow Ey)\,.$

Initial segments of activities, in contrast, are of the same type as the activity in question. This characteristic property is expressed by (11b).

A mere classification like (11) does of course not explain the aspectual difference. Krifka (1992) pursues the idea to derive the aspectual class of an event type from properties of the thematic relation that is borne by the affected objects (the patients, themes, or whatever) to the affecting events. The explanatory mechanism is a "transfer" of mereological properties by thematic relations.[18] Krifka's approach, though aiming in the right direction, is not capable of an adequate represention of the temporal dimension of changes and events. Verb of motion examples like *John walked to the store* seem not to involve an object that is incrementally affected. At least this assumption would call for a rather indirect and artificial construction.

In the following, we propose a more flexible framework which does not put all the burden on a thematic relation. Suppose E is an event type of sort accomplishment. The termination point of type E events has to be characterized by a condition on their active arguments. This condition necessarily depends on the event type. To this end, let us assume an operation Π which takes an event type E to a functional relation between time points and entities such that $\Pi E\, xy$ iff at time point x the event of which y is an active argument with respect to E terminates or is already over.

If, for example, E is the class of eating events then the things eaten bear the relation ΘE to the corresponding eating events and ΠE is borne by those time points to the things eaten at which they are eaten up. Since 'ΠE' does not make reference to events of any type, the termination condition does not depend on event tokens, as desired. Reversible accomplishments like *John filled a bottle* and *John emptied a bottle* make this point clearer. In both cases, the active argument is a bottle. Π takes the first event type to a relation which is borne by time points to bottles that are full at that time. Application to the second event type, on the other hand, leads to emptiness.

Let ΔE be $\Pi E \circ \Theta E$. By definition, Ex iff $(\Pi E \circ \Theta E)(\omega`x, x)$. Note that the end point of a type E event that bears ΔE to an event x is not necessarily the end point of x. This can happen, for example, if the same bottle is involved in successive fillings and emptyings. The distinction between accomplishments and activities relies on the state the active argument must be in when the corresponding event terminates. This state holds the first time during an event at its end if the event is of type accomplishment, as expressed by (12a). For activities, in contrast, the state holds as soon as the event has started, formalized by (12b).

(12) a. $\forall x(Ex \;\rightarrow\; \Delta E(\omega`x, x) \wedge \forall y(\alpha`x \leq y < \omega`x \;\rightarrow\; \neg\Delta E\, yx))\,.$

[18] The formal definition uses lattice homomorphisms.

b. $\forall x(Ex \;\rightarrow\; \forall y(\alpha`x < y \leq \omega`x \;\rightarrow\; \Delta E\, yx))\,.$

Let us call the crucial property of the active argument the *transition* property in case of activities and the *result* property in case of accomplishments. If the event is of type *pushing a cart* then the transition property of the cart is that it has moved by having been pushed, if the event is a walk of John then John is the active argument and his having changed location by walking counts as transition property.

But, obviously, also accomplishments define transition properties for their active arguments. At the linguistic level they show up as continuous forms. If the event type is the eating of an apple then, as soon as the event has started, parts of the apple have been being eaten. Therefore, we assume an additional operation Π_0 besides Π, which gives the transition property of the active argument and coincides with Π in the case of activities.[19] The analysis given in section 4 of the twofold frame point of *until*-clauses containing accomplishments relies heavily on these two properties of the active argument.[20]

Our approach to capture the dual character of the notion of change has much in common with the two-level dynamic architecture as put forward by van Benthem (e.g. 1996), which allows static tracing of dynamic procedures by the interaction of *static projections* and *dynamic modes*, the former taking procedures to propositions and the latter taking propositions to procedures. An example of a projection is the test operation ? of section 1.2. A dynamic mode of particular interest in the current context is the so-called *minimal* (or *strict*) *updating* given in (13).

(13) $\quad \mu\text{-bec}\, P \;=\; \{xy \mid x < y \;\wedge\; Py \;\wedge\; \forall z(x \leq z < y \rightarrow \neg Pz)\}\,.$

Extending the terminology of Dowty (1979) minimal updating could be called the *minimal become* operation (see Naumann, 1997a,b). Because of its structural similarity to (12a) this mode characterizes in a sense the event types of sort accomplishment.[21] It can easily be lifted to Dynamic Event Logic. Propositions are then transformed into event types as specified in (14).

(14) $\quad \mu\text{-bec}\, P \;=\; \omega\!:\!P \;\wedge\; \neg\Diamond^{\downarrow}(\omega\!:\!P) \;=\; \omega\!:\!P \;\wedge\; \Box^{\downarrow}\neg(\omega\!:\!P)\,.$

3 Temporal Clauses

3.1 Reference Time

It is generally assumed that the primary function of a temporal subordinate clause consists in determining a time (i.e. an interval or a time point) with respect to which the main

[19] As the attentive reader will notice, we shift the burden of explanation to a good part to the proper explication of ΠE and $\Pi_0 E$. See Naumann, 1995, for details.

[20] Questions of aspectual composition and aspectual shift have to be put aside here. For example, the shift from *walk* to *walk to the station* modifies the aspectual class of the event type by adding a result property of the active argument. Also a change of the active argument seems to be possible, as in alternations like *John loaded hay into the wagon* and *John loaded the wagon with hay*.

[21] The identity between $(\mu\text{-bec}\, P)``\top$ and $\neg P\, \text{until}\, P$, using definition (5), hints at a close relationship between the semantics of achievements and *until*-clauses. Note that this is a case of a *strict until*-condition because both predicates are *logically* incompatible.

clause is interpreted in accordance with the temporal relation expressed by the temporal conjunction. Consider the examples in (15).

(15) a. While John watched TV, Mary worked on her dissertation.

b. When Mary arrived, Bill was watching TV.

Assuming that John watched TV from two o'clock to four o'clock and that Mary arrived at noon, the sentences in (15) remain true if the temporal clauses are replaced respectively by *between two o'clock and four o'clock* and *at noon*. Since temporal adverbials of this kind are usually taken to determine (or at least to restrict) the reference time of the main clause, it seems reasonable to attribute the same function to the respective temporal clauses. A first hypothesis then is that the reference time of the main clause coincides with the reference time of the temporal clause (which is the event time for the examples in (15)). This is an instance of what Hamann (1989) calls an *indirect* approach to the semantic analysis of temporal conjunctions. What is temporally ordered by the temporal conjunction are assumed to be the reference times and not the event times of main and temporal clause.[22]

As observed by Hamann, the assumption that temporal conjunctions directly order the reference times is not without problems, as shown by examples involving temporal measure phrases like *two seconds before*. Because of this and other problems Hamann raises the question of whether the notion of reference time should at all be used for the interpretation of temporal clauses. Based on the difference between the interpretation of (3a) and (3b) Hitzeman (1991) and Tovena (1995) put forward a similar argument. That the interpretation of *until*-sentences depends on the aspectual class of the sentence in the *until*-clause poses a problem for both indirect and direct approaches: Despite their difference in aspectual behaviour, the sentences *John walked* and *John walked to the store* can be used to refer to the same event. In this case, there is only one event time, which is identical to the reference time (since both sentences have simple tense). Thus, independently of the temporal relation expressed by *until*, the use of these sentences in *until*-clauses should lead to the same range of interpretations, contrary to the data.

In this respect *until* differs from other temporal conjunctions like *while* or *after*. In contrast to *until* these temporal conjunctions do not impose aspectual restrictions on the main clause. This does not imply that the interpretation of the temporal relation cannot be sensitive to the aspectual properties of the modified expression. For instance, if the modified sentence is of type accomplishment or achievement, *while* requires the event denoted by the main clause to (completely) occur on the interval denoted by the temporal

[22] A standard argument against *direct* approaches, which assume temporal conjunctions to impose a temporal order directly on the event times, is that they cannot explain the difference between (a) and (b).

a. When John left, Mary breathed a sigh of relief.

b. When John had left, Mary breathed a sigh of relief.

(According to common wisdom, the perfect is interpreted as expressing a relationship between event time and reference time whereas tense morphemes are interpreted as determining the relationship between speech time and reference time.)

clause whereas for sentences of type state or activity the event time can properly include the run time of the event denoted by the *while*-clause. On the other hand, *while* does impose an aspectual restriction on the subordinate clause. Aspectual classes like achievements or points that correspond to event types denoting point-like events are excluded, or are only acceptable if the *while*-clause is interpreted as a progressive or an iteration. What is aspectually distinguished by *while* therefore are point and achievement expressions from accomplishment and activity expressions.[23] Thus, whereas the aspectual restriction imposed on a *while*-clause concerns the distinction between atomicity and non-atomicity, the aspectual restriction imposed on an *until*-clause concerns a different (aspectual) level.

As the examples in (3) show, an *until*-clause always determines a time point (its frame point) even when it denotes a (non-minimal) interval, as this is the case for accomplishment and activity expressions. Furthermore, the fact that for an activity expression in the *until*-clause only the beginning and not the end point is a possible frame point shows that in addition a point must be characterized by some property that is not purely temporal in order to be determinable. Further evidence is provided by the adverbial use in examples like *John was jobless until December*, which allows two readings. According to the first, John had no job at least until the beginning of December. On the second reading he was jobless at least until the end of December.[24] Taken together, *until* differs from *while* in imposing no requirement on the length of the interval in the temporal clause and specifing a time point whereas *while*-clauses define a non-minimal interval and specify an interval.

Another question that naturally arises in connection with temporal clauses is whether it is possible to anaphorically refer back to their reference time. In general, the answer in negative, as example (16) illustrates.

(16) After John left, Mary breathed a sigh of relief. This was at six.

It is the reference time of the main clause that is referred to. Only if the temporal conjunction permits the reference times of both clauses to coincide, the reference time of the temporal clause might (accidentally) also be referred to. An example is (16) with *after* replaced by *when*.

3.2 The Semantics of *Until*

To reveal the semantic function of *until*, recall that the event denoted by the main clause must go on at least up to the frame point of the *until*-clause. Viewed from this perspective the semantic function of an *until*-clause is similar to that of a *for*-adverbial.[25] It imposes a lower bound on the run time of the event denoted by the main clause.[26] The aspectual

[23] For suggestions how to analyze achievement and point verbs see Pinon (1997) or Naumann (1997a).

[24] There is a third reading according to which John was jobless at least up to some point in December. In this case, December is taken as an element of the sequence of months. On this reading John was without a job at least until December as opposed to November or January.

[25] This observation is also made by Hitzeman (1991).

[26] Note that *for*-adverbials are in general interpreted in a non-strict sense, i.e., they allow the run time to be longer than the interval denoted by them.

John ran for ten minutes. In effect, he ran for twenty minutes.

restriction imposed by *for*-adverbials is exactly the same as that imposed by *until* on the main clause.[27]

(17) a. John wrote/finished the letter in ten minutes/*for ten minutes.

b. Bill ran/was ill *in ten minutes/for ten minutes.

Only expressions of type activity or state can be modified by a *for*-adverbial. Accomplishment and achievement expressions are both excluded. For *in*-adverbials one gets the inverse behaviour. Furthermore, in contrast to temporal adverbials like *during the night* or *after midnight* neither *for*- nor *in*-adverbials can be interpreted as restriction on the reference time relative to which the unmodified sentence is evaluated. Semantically, a *for*-adverbial takes an event class to the subclass of all events whose run time is at least of the length of the interval denoted by the argument-NP of the *for*-adverbial. Elements of this subclass can then be related to an independently given reference time. Thus, a *for*-adverbial directly restricts the run time of an event by imposing a lower bound on its length, independently of any reference time that is specified by some other constituent.

Until-clauses differ from pure duration adverbials in that they at least partly determine the reference time of the main clause.[28] For instance, *John ran until Mary arrived* only asserts that on the interval $[x, y]$ John ran (was running) where y is the frame point of the *until*-clause (the time of Mary's arrival) and x is given contextually. This is compatible with John running beyond y up to some time point w. But it is equally compatible with John having been started to run at some v before the contextually determined x. The interval $[x, y]$ with respect to which it is required that John ran in order that *John ran until Mary arrived* is true, is then only a subinterval of run time of John's maximal running event $[v, w]$. But this is exactly the condition that must hold between reference and event time in the case of durative (imperfective) expressions. It is therefore possible to interpret the interval $[x, y]$ as the reference time with respect to which the main clause of the *until*-sentence is interpreted. It follows that an *until*-clause partly determines the reference time of the main clause by setting its right border to the frame point. Consequently, the run time of the event denoted by the main clause is indirectly restricted by the requirement to enclose $[x, y]$.

In contrast to *while*, for example, the semantic function of an *until*-clause does therefore not consist in temporally ordering the reference (or event) times of the main and the temporal clause. The semantic function of an *until*-clause is similar to that of temporal adverbials like *yesterday* or *at noon* by determining the reference time of the main clause, i.e. the clause they modify. The difference consists in the way the reference time is determined. Whereas temporal adverbials like *yesterday* determine it completely, an *until*-clause only determines its end point. The difference between *until* and *while* can be summarized as follows: *While* does not determine the reference time of the main clause and imposes a temporal order on the reference times. *Until* partly determines the refer-

[27] The analogy also holds for point verbs like *hit* and *knock* where the modification with *for*-adverbials triggers an iterative reading, witness (9).

[28] See also Hamann, 1989.

ence time of the main clause and does not impose a temporal order on the reference times of main and subordinate clause.

4 Synthesis

What remains to be done is to integrate the above analysis of *until* into the formal framework of section 2. Recall that the relation ΔE, which is defined as $\Pi E \circ \Theta E$, is borne by those time points to an event x of type E, at which x terminates or is already over. This is the case, if E is of sort accomplishment. For activities, on the other hand, every time point at which x is taking place bears this relation to x too.

The earliest of these points after the beginning of the event is a possible frame point for an *until*-clause of type E. Let ΩE be the functional relation given by

$$(18) \qquad (\Omega E)`x \; = \; \min_{\leq}\{y \mid \alpha`x \leq y \wedge \Delta E\, yx\}\,.$$

Similarly, let $\Omega_0 E$ be the relation defined as (18) with ΔE replaced by $\Pi_0 E \circ \Theta E$. Then, $(\Omega_0 E)`x$ is the first time point at which x is taking place, irrespective of the aspectual class of E. ΩE coincides with $\Omega_0 E$ if E is of sort activity (or state), and gives the culmination point of type E events for accomplishments.

Taken together, $\Omega_0 E$ and ΩE determine the possible frame points of *until*-clauses of type E. This leads to the following (approximate) analysis of *until*:

$$(19) \quad D\,\mathrm{until}\,E \; = \; \{x \mid \exists yz(Dy \wedge Ez \wedge x \trianglelefteq y \wedge (\omega`x = (\Omega_0 E)`z \vee \omega`x = (\Omega E)`z))\}\,.$$

The specified eventualites are the initial segments of the eventuality denoted by the main clause 'D', which end at one of the frame points determined by the subordinate clause 'E'. A minor and straightforward modification of (19) would integrate the reference time of *until*-sentences in accordance with section 3.2. It has to be emphasized that the remaining indeterminacy concerning the actual choice between the possible frame points is not part of semantics but, as Steedman (1997) notes in the related case of *when*-clauses, a matter of knowledge representation and processing.

The aspectual restriction imposed on the main clause is not accounted for by (19). Neither event types of sort accomplishment nor of sort achievement are excluded. This additional restriction is formulated as a *presupposition*. Since the *until*-clause functions as a restriction on the end point of the main clause, it is presupposed that this point *is* potentially restrictable. This excludes telic event types which determine their end point inherently, such as accomplishments and achievements. A more satisfying explanation, which we have to postpone, would work on the basis of a fully developed theory, which, first, analyzes accomplishments as "incorporated" (strict) *until*-clauses (as already sketched in section 2.2), and, second, allows to derive that an iteration of *until*-adverbials is impossible on axiomatic reasons. Though at an early stage of development, we regard our approach as a promising step towards such a calculus.

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