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A Constraint-Based Grammar of English Temporal Connectives

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A Constraint-Based Grammar of English Temporal Connectives

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Abstract:

This document describes a set of feature structure representations for English temporal connectives. Their lexical entries are described and motivated in detail, along with a type hierarchy that will be used in the computational HPSG/DRT system we are building to parse texts containing these temporal connectives. This work is based on the TTT proposal for Dutch temporal connectives described in [Oversteegen, 1989, Oversteegen, 1993] and on Martin's [1992] system representing the ideational (external) meaning of temporal relations in English.

Contents

1 Introduction

This document describes a set of feature structure representations for English temporal connectives. Their lexical entries are described and motivated in detail, along with a type hierarchy that will be used in the computational HPSG/DRT system we are building to parse texts containing these temporal connectives. This work is based on the TTT proposal for Dutch temporal connectives described in [Oversteegen, 1989, Oversteegen, 1993] and on Martin's [1992] system representing the ideational (external) meaning of temporal relations in English. The representations described here are used in combination with the tense and aspect representations described in Deliverable R2.3.1a.

The general idea behind the Oversteegen analysis of temporal connectives is that their temporal and non-temporal meanings are strongly related in the sense that to get one reading of a connective like *when* certain conditions must hold (In practice, this will translate as "the features of the lexical item must have certain values") and to get the other reading a different set of conditions must hold, but there is a high degree of overlap between these two sets of conditions. Rather than depending on world knowledge, these conditions relate to more concrete elements of a text such as presuppositions and lexical information.

There are three tasks involved in describing this analysis and the related computational work: First, the hierarchy of conditions for the connectives must be specified. For English, this has already been done by Martin [1992], a system which we will take as our starting point, and which will be described in Section 2. In Section 3 we will restructure Martin's system by moving some constraints into the lexicon and by modifying his hierarchy so that we can make efficient use of it in a unification system. The Oversteegen system for Dutch connectives allows both temporal and nontemporal senses of the connectives to be included in the same hierarchy and provides TTT representations for these senses, and in Section 4 we will integrate these ideas into our modified version of Martin's hierarchy. Finally, in Section 5 we will describe the lexical entries for the English connectives and discuss how the various readings are derived computationally.

2 Martin's system of temporal connectives

Martin's [1992] system of temporal connectives is shown in Figure 1. Each node of the tree has certain requirements associated with it, so, for example, *before* has the qualities *successive*, *following* and *posterior dependent*, and for *before* to be used felicitously in a sentence it must pass a test for each of these qualities. The following list describes the requirements, where α refers to the event described by the main clause and β by the subsentence:

1. SIMULTANEOUS: There is some intersection between the time at which α occurs and the time at which β occurs.
   SUCCESSIVE: α follows β, or vice versa, with no intersecting time points.
2. COEXTENSIVE: The time during which α occurs is contained within the time at which β occurs, or vice versa. (Avoid interpreting "α is coextensive with β" as "α occurs over the same interval as β."
   OVERLAPPING: There is not a subset relation between the time at which α occurs and the time at which β occurs. (Because all OVERLAPPING constraints are combined with the SIMULTANEOUS constraint, this definition is sufficient.)
3. FOLLOWING: α occurs (not immediately) after β or vice versa.
   FOLLOWING IMMEDIATELY: α occurs immediately after β or vice versa.
4. DURATIVE: β is an eventuality of some duration.
   PUNCTILIAR: β is an eventuality which is interpreted as occuring at an instant.
5. DURATIVE ANTERIOR DEPENDENT: β is an eventuality of some duration, occurs prior to α, and has some rhetorical link to α.
   PUNCTILIAR POSTERIOR DEPENDENT: β is an eventuality which is interpreted as occuring at an instant, occurs after α, and has some rhetorical link to α.
6. STATIVE: β is stative.
   NONSTATIVE: β is a process or event.
7. NONDEICTIC: β generalises over times.
   DEICTIC: The time of β is related to speech time.
8. RELIEF: There is some expression of relief that the posterior event is getting underway.
   RELIEF UNMARKED: There is no such expression of relief.
9. EXTENSION TO PRESENT: The time described is an interval from some point in the past up until the present.
   EXTENSION FROM PRESENT: The time described is an interval from the present to some point in the future.

Figure 1. Martin’s system for temporal connectives.

3 How the information from the text is used

In order to use a hierarchical system like Martin's in a unification-based system like our computational HPSG module, we need to consider what types of information his constraints make use of and what type of hierarchy best suits those constraints from a unification perspective. First, consider that we can determine which of Martin's constraints are applicable and therefore which connectives are available for use by making use of the following types of information:

1. **Lexical information which directly indicates a certain constraint.** Examples include temporal expressions such as *yesterday* which are deictic, an expression such as *relieved* which will point to the type *relief*, a verb such as *leave* which is lexically marked as *punctiliar*, and an expression such as *immediately* as in *After John arrived he immediately went to the phone* will directly indicate a *following immediately* type.
2. **Planning information.** Sometimes the constraint is hidden in planning information such as prerequisites or results of events. For example, if α is *John ate a huge meal* and β is *He felt quite full*, planning information tells us that α and β are *dependent* and that they are *successive*, and, moreover, that β is the posterior event. Planning information is related to rhetorical information in that a plan has a goal, prerequisites for meeting that goal, and results of that goal; in general, a prerequisite is related to the goal by the rhetorical relation of *enablement*, and the goal is related to its results by the rhetorical relation of *causality*.
3. **Rhetorical relations.** Rhetorical relations can constrain the possible temporal relations between α and β. For example, if α causes β, then α must precede β, so we know we have a *successive* relation.
4. **Aspectual information.** The aspect of an eventuality[1] is marked on the verb and may change as the semantics of the sentence is determined compositionally. If the sentence is stative, Martin's constraint *stative* is assigned directly, and additional information can be determined when rhetorical, planning and aspectual information are combined, as will be discussed below. Furthermore, *coercion information* [Moens, 1987, Moens and Steedman, 1988] will be useful in explaining why a telic such as *kick the tyre*, which is predicted to be unacceptable with **while**, can be acceptable if it has an iterative reading, as in *While I kicked the car's tyre, John checked the trunk.* In certain cases an element of one aspectual class can be *coerced* into another class.

Many of the constraints in Martin's system relate to the possible temporal relationships between the eventualities described by α and β. To determine these possible relationships we can make use of work done for discourse understanding on the LRE project "Towards a Declarative Theory of Discourse," in which tense, aspect, rhetorical relations and cue phrases are used to mutually constrain each other and thereby reduce the number of possible temporal relationships [Hitzeman *et al.*, 1994, Hitzeman *et al.*, 1995]. In generating, this system should help us constrain the possible uses of connectives. As an example of how this system works, consider the following type hierarchy:

[1]This term, from [Bach, 1981], refers to a member of one of the aspectual classes: event, state and process.

(1) RHET
- JUST_BEFORE
  - SEQUENCE
  - CAUSES
- OVERLAPS
  - BACKGROUND
- PRECEDES
  - RESULTS
  - REVERSE_SEQUENCE

If the type RHET takes on the value marked on any one of the nodes of this tree, it necessarily takes on the value marked on the parent of that node and a disjunction of the values of the children of the node. For example, if clues such as cue words or tense tell us that α occurs *just_before* β, then we know that we either have a sequence of events (with no causal relation between them) or α causes β. In this fashion, by making use of any partial information we have concerning the temporal relations between α and β, we can narrow down the possible rhetorical relations (such as *sequence* and *causes*) as well. The property that allows this tree to serve as an underspecified representation of the temporal relations is written formally below:

(2) If we know that clause α is related to clause β by relation X, where X is marked on a node of the tree, then we also know that clause α is related to clause β by the relation marked on the parent of X, by one of the relations that is marked on a child of node X, and not by any relation marked on the sisters of X.

To see the improvement constraint (2) gives us, compare Martin's tree in Figure 1 with the tree in (1); the former does not have property (2) and the latter does. Suppose that we have verified that one of the constraints marked on a node of each tree holds. In Martin's tree, we still need to verify that the constraints on the parent and child nodes hold. For example, if we know that β is stative we still have to verify that the DURATIVE ANTERIOR DEPENDENT, OVERLAPPING and SIMULTANEOUS constraints hold in order to know whether we can use that interpretation of **while/when**. With the tree in (1), however, if we have verified that one of the constraints on one of the nodes hold, we can rely on property (2) to give us further information. For example, if we know that we have a PRECEDES relation between α and β, then we also know that we don't have a JUST_BEFORE or OVERLAPS relation, and that we have either a RESULTS or a REVERSE_SEQUENCE relation. We don't need to verify any of the constraints marked on nodes higher in the tree, and we have narrowed down the possibilities for relations marked on lower nodes of the tree.

Our task, then, is to modify Martin's tree in Figure 1 so that it has property (2). The hierarchy we construct will serve a slightly different function than that described in [Hitzeman *et al.*, 1994, Hitzeman *et al.*, 1995]: Hitzeman *et al.* argue that an explicit marker such as a temporal connective or cue word can override information from tense and aspect, so these sources of information won't be as useful to our purpose. However, this hierarchy will allow us to rule out sentences such as (3) that have clashes between the connective and another explicit cue word or temporal expression:

(3) #After he left he first put on his coat.

It will also explain bizarre readings of examples such as (4):

(4) ?John worked in the garden while his cousin appeared.

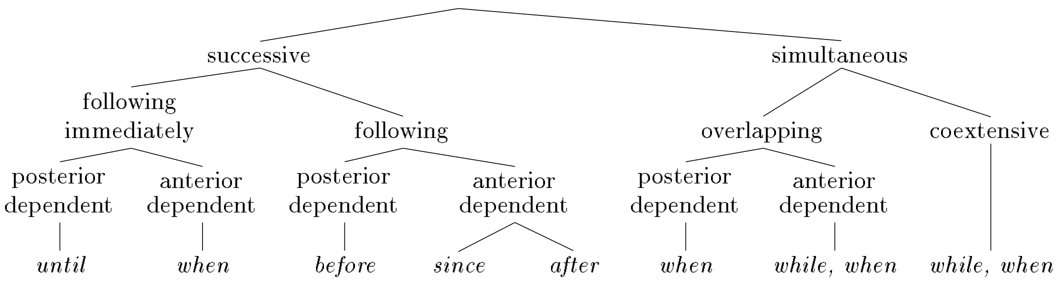
Our hierarchy will tell us that this use of **while** requires α and β to be coextensive, so the appearance of the cousin gets the bizarre interpretation of occurring over an extended time interval.

3.1 Modifying Martin's system

One simplification we can make is to move aspectual constraints (e.g., *as* requires a non-stative β) and constraints of durativity (e.g., *while* requires a durative β) into the lexicon, implementing them in terms of constraints in the definitions for the individual connectives.[2] We can do this by creating types ASPECT and DURATIVITY to put inside the SUBCAT and MODS types of each connective that places such constraints on the sentences it subcategorizes for or modifies.

We can also eliminate the distinction between *deictic* and *nondeictic* connectives. This distinction may be important for categorising connectives, but, for the purpose of implementation, the fact that *since* is deictic (i.e., its semantics involves the interval of time between speech time and whatever time is expressed by its subcategorized object) is more efficiently processed in a temporal constraint propagation module. In other words, any time *since* is used it will be used deictically, and if the time interval it denotes is inappropriate we cannot know this without checking other temporal constraints for consistency with this use of *since*. Consequently, the distinction between the nondeictic aspect of *after* and the deictic aspect of *since* will be apparent only in their semantics.

We are now left with the following simplified tree:



One problem remains for effective use of this constraint tree: although the first two tiers of the tree follow constraint (2), the third tier doesn't, and, as a result, we don't make use of all the information given by cue words.. Consider example (5):

(5) Mary left the building after first checking all the locks.

The cue word *first* marks the event that occured first. Assume that there is a slot TEMPORAL_RESTRICTION in our feature structure that takes as its value the subtype marked on one of the nodes of the tree above. Because *first* tells us that the events α and β are successive rather than simultaneous, we can give TEMPORAL_RESTRICTION a *successive* value. We have

[2]Note that both aspectual and durativity constraints are necessary because it is possible to have both durative and punctual states and telics.

made use of the information that the events occured successively, but we have lost the information concerning <u>which</u> event occured first. In this example, β occurs first, so we want to mark the *anterior dependent* node under *following* if α follows β or under *following immediately* if α immediately follows β. We haven't figured out yet which of these relations holds, so we would have to give the TEMPORAL_RESTRICTION slot the value *successive* $\wedge$ *((following* $\wedge$ *anterior-dependent)* $\vee$ *(following-immediately* $\wedge$ *anterior-dependent))*. This solution is overly messy both in terms of computation and readability, and doesn't give us the desired effect of having the information from planning, aspect, cue words, etc. help us arrive at the single most appropriate and restrictive node of the tree.

We can avoid this problem by rearranging the tree to separate those connectives that indicate that α precedes β from those that indicate that β precedes α, as in the tree shown in (6):

(6)

- successive
  - α anterior
    - *after, when, since*
  - α posterior
    - *before, until*
- simultaneous
  - overlapping
    - *while, when*
  - coextensive
    - *while, when*

Using this tree, when we process a cue word such as *first* we can determine whether it marks α or β and set the value of TEMPORAL_RESTRICTION to either *posterior* or *anterior*, accordingly. Note that in order to form this tree, we have made two simplifying assumptions: that any overlap relation is not one in which there is an anterior or a posterior eventuality (Any such relation will be treated as successive), and that the *following* vs. *following immediately* distinction is not crucial. The latter assumption can be justified with examples such as the following:

(7) John didn't get married until his mother died.
(8) John moved to Brazil when his mother died.

It is quite plausible that John waited for months after his mother's death before getting married or moving to Brazil, an intuition which raises doubts that this sense of **until/when** should be treated as *following immediately* rather than simply *following*.

(We have only treated here the connectives that were treated in Dutch, which eliminates from Martin's system *once*, *as soon as* and *as*. Note, however, that *as* can be dealt with like the other connectives in its same tree position, and that *once* and *as soon as*, which are distinguished by the features *relief* and *relief unmarked*, can be dealt with through lexical and planning information, as are other features described in Section 5.)

4 Incorporating Oversteegen's approach

Oversteegen [1989, 1993] extends and modifies Martin's system to deal with Dutch connectives, both temporal and nontemporal senses, and relates this modified system to the TTT approach. Our purpose here is to take the above modification of Martin's system, which is well-suited to our computational goals, and to incorporate Oversteegen's changes so that we handle both temporal and nontemporal senses of these English connectives.

We will begin by comparing the *simultaneous* branch of the simplified tree in (6) to Oversteegen's *simultaneous* subtree:

(9) Our *simultaneous* subtree:

- simultaneous
  - overlapping
    - *while, when*
  - coextensive
    - *while, when*

(10) Oversteegen's *simultaneous* subtree:

- simultaneous
  - overlapping
    - mere overlap
      - *toen*
    - includes
      - *toen*
    - is included
      - *toen, terwijl*
  - coextensive
    - duration
      - iterative
        - *terwijl*
      - not iterative
        - *toen, terwijl*
    - punctiliar
      - *toen*

Each of the leaves in Oversteegen's tree is associated with a series of constraints that must be met for the connectives associated with that leaf to be used. Our task is to incorporate the differences in Oversteegen's system either into our tree or into the lexical items, while maintaining that property of the tree given in (2) and repeated below:

(11) If we know that clause α is related to clause β by relation X, where X is marked on a node of the tree, then we also know that clause α is related to clause β by the relation marked on the parent of X and by one of the relations that is marked on a child of node X.

For the moment, let us assume that each series of constraints associated with a leaf of Oversteegen's tree can be implemented in the lexicon; how this is to be done will be discussed in detail in the next section.

Oversteegen's *overlapping* subtree follows the constraint in (11), and so can be directly adopted as long as the Dutch readings are the same for English. We will discuss this in Section 5 and ultimately we will collapse the three categories into one by moving the constraints into the lexicon.

Oversteegen's *coextensive* subtree, however, does not follow the constraint in (11); note, for example, that if β is punctiliar, it is not necessarily the case that α and β are coextensive. We can eliminate this problem by putting the punctiliar/durative constraints into the lexical entries for *when* and *while*, as we did when simplifying Martin's tree. We can eliminate the *iterative/non-iterative* distinction in English, because (as Oversteegen notes) *when* in English is unacceptable when α is a process; if we take the standard assumption that any event that is iterated is a process, we have a way of ruling out *when* with iterative α while not ruling out *while*. This can be specified in the lexical entry for *when* rather than in the tree.

Our resultant simultaneous branch is shown below:

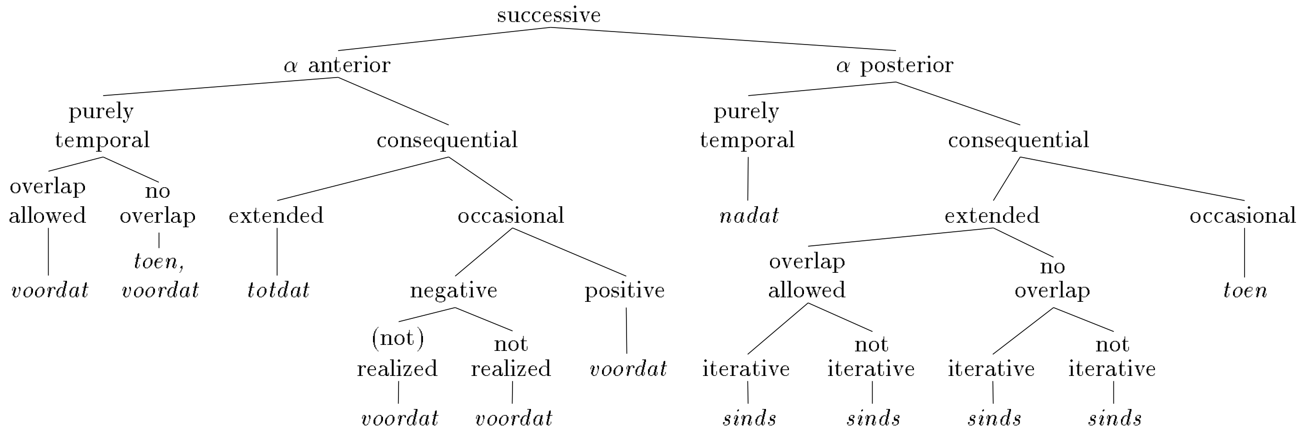
simultaneous

overlapping coextensive

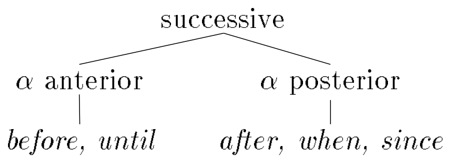
when, while *when, while*

The next task is to reconcile Oversteegen's *successive* branch with ours. Note that because Oversteegen places more emphasis on the main clause than Martin, she uses the terms *anterior* and *posterior* to refer to the status of α rather than β, reversing Martin's use of the terms. The corresponding switch has been made in our tree. Both trees are shown below:

(12) Oversteegen's *successive* subtree:



(13) Our *successive* subtree:



There are a few terms used in Oversteegen's *successive* subtree that need defining before we precede:

1. CONSEQUENTIAL: From Sandström [1990]: An event e′ is consequential upon an event e if:
   (a) e causes or takes part in causing e′
   (b) e creates or takes part in creating the appropriate conditions for e′ to take place
   (c) e evokes or is part of what evokes e′ as a response; or
   (d) one of the relations (a) – (c) holds between e′ and e″ together (and possibly more events) and another event e (or several other events).
2. EXTENDED: The proposition expressed by the main clause is true over the interval expressed by *since/until*.
   OCCASIONAL: The proposition expressed by the main clause is true on a certain occasion within the indicated time frame.
3. NEGATIVE/POSITIVE: Negative contexts change the reading of *voordat*, giving it a counterfactual or noncommittal reading.

Again, several simplifications of this tree can be made; they will be listed here but described in detail and justified in Section 5. First, the nodes *overlap allowed/no overlap* and *extended/occasional* can be expressed as type constraints in the lexical entry for the individual connective. Specifically, **toen (when)** will not allow overlap between α and β but **voordat (before)** will; **totdat (until)** will select for an atelic α, allowing us to eliminate the *extended* restriction, and **voordat (before)** in English allows either an extended or an occasional α, so the distinction can also be eliminated; consequential **toen (when)** will select for a telic, allowing us to eliminate the *occasional* constraint, and **sinds (since)** in English can take both a telic or an atelic α but associates them with different readings, as will be discussed in Section 5.6.

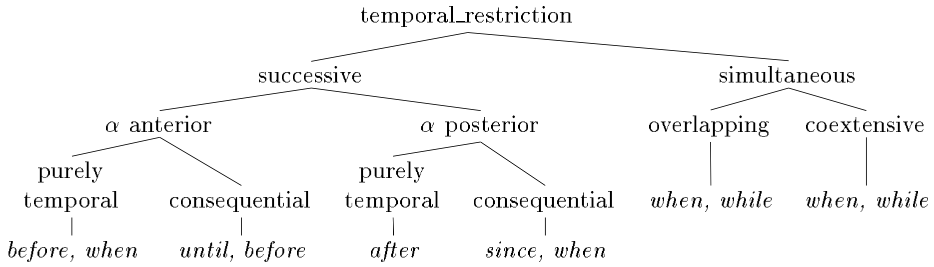
Second, the *iterative/non-iterative* distinction can be eliminated for **sinds (since)** in English for two reasons: we can handle iteration by means of an algorithm like that of [Moens and Steedman, 1988] that allows coercion of elements of certain aspectual classes into other aspectual classes, thus reducing the *iterative/not iterative* constraint into a constraint on what aspectual classes are acceptable with a connective. Also, the difference in readings that **since** has with members of different aspectual classes can be dealt with in the lexicon, as will be discussed in the section on **since**.

Third, the distinction between the three *overlapping* categories will become unnecessary, and will be treated in the TTT formula instead.

Finally, the possibility that the β event need not actually occur with **voordat (before)** in negative contexts will be dealt with as part of the system that deals with planning, as we will argue.

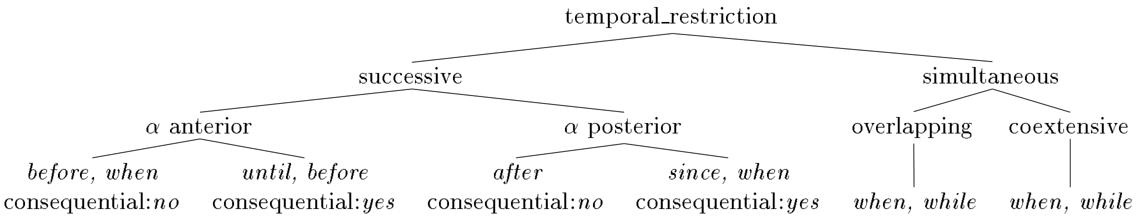
We have now arrived at the following hierarchy:

(14)



The duplicate *purely_temporal* and *consequential* nodes still violate constraint (2). By treating them as features rather than types in the hierarchy, we arrive at the final representation of the hieararchy, below:

(15)



By treating consequentiality as a feature rather than a type in the hierarchy, our type hierarchy is made subject to constraint (2) so that it serves us computationally, and the CONSEQUENTIAL feature acts as an additional constraint that must be verified, but which neigher gives us the hierarchical information that constraint (2) provides nor upsets the advantage that constrant (2) provides.

Using this hierarchy, we can use the information described in Section 3 to constrain the contexts in which the connectives are felicitous. For example, if planning formation tells us that γ is a prerequisite of δ, then we expect a successive relation. By determining whether γ is the eventuality described by the main sentence or the subsentence, we can further constrain the TEMPORAL_RESTRICTION type to either α *anterior* or α *posterior.* α *posterior* will allow the use of connectives *after*, *since* or *when*, but not others.

5 A representation of the English temporal connectives

By settling on the hierarchy in (14), we are effectively making the claim that several of the paths in Oversteegen's hierarchy can be collapsed in our computational system. We will now justify this claim by describing Oversteegen's constraints on the various paths through her hierarchy and discussing how we can collapse paths by moving information into other areas such as the lexicon. We will also discuss when the Dutch readings differ from the English readings.

(Note that while Martin refers to the main sentence event as α and the subsentence event as β, Oversteegen uses E_m and E_s, respectively.)

5.1 *When*

When can be reached through seven branches of Oversteegen's tree and through four of our tree. We have collapsed the following two paths into our one branch SIMULTANEOUS:COEXTENSIVE:

(16) SIMULTANEOUS:COEXTENSIVE:PUNCTILIAR
When the dog barked, the judge sneezed. (Martin 4.44b)
(17) SIMULTANEOUS:COEXTENSIVE:DURATION:NOT ITERATIVE
When we were waiting, we felt confident. (Martin 4.28)

These are both readings where E_s and E_m are coextensive, so either both E_s and E_m are punctiliar or they are both of some duration. Rather than use the hierarchy to specify this, we can make use of the TTT feature structures described in Deliverable R2.3.1a: Specifically, we can require that they both either be singleton lists (punctiliar) or proper lists (durative).

Oversteegen's constraint on path (17) that E_s is non-iterative isn't necessary in English, because any iterated event is a process, and English *when* can't have a processive E_s at all, as shown in (18):

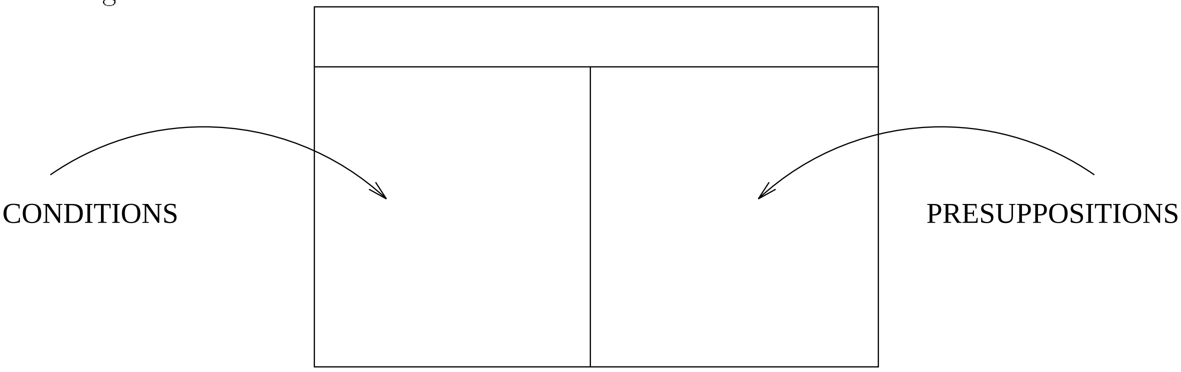
(18) ?When John walked in the park he lost his key. (Oversteegen 33b)

As a result, we can put a restriction in the lexical entry for **when** saying that it can't take a processive E_s, and eliminate the NOT ITERATIVE constraint from the hierarchy.

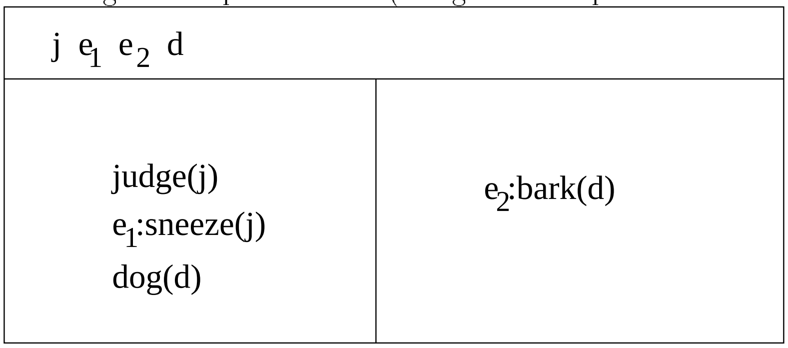
We also need to incorporate into this reading of **when** the constraints Oversteegen places on paths (16) and (17). She specifies the following constraints for paths (16) and (17), respectively:

(16′) ∘ E_s is presupposed
∘ E_s and E_m are terminative events
∘ deictic constraint
(17′) ∘ E_s is presupposed
∘ E_s and E_m are processes/states
∘ deictic constraint

The constraint that E_s is presupposed is intended to mean that E_s is part of the common ground, allowing this reading of *when* to be distinguished from narrative *toen*, which introduces an E_s that is new. To treat presupposition, we require a DRS construction rule that is triggered in some way by the presupposed item, and which then creates a DRS such as the following:



For example, for the sentence *When the dog barked the judge sneezed* we would arrive at the following DRS representation (along with temporal and other information, of course):



An attempt would then be made to verify the presupposed condition by checking the conditions introduced into the DRS by the previous discourse. If verified, it is deleted. If not, it is accommodated through adding it to the left hand side of the DRS. We will use the type PRESUPPOSED as a simple way of listing in the lexical entry for a connective items we know to be presupposed, and thereby providing a trigger for the DRS construction rule described here.

The deictic constraint refers to the observation that Dutch *toen* can only be used in combination with a past tense, unlike English *when*. We can therefore ignore this constraint.

Our branch SIMULTANEOUS:COEXTENSIVE is now sufficient to describe both readings of **when**. The constraints on the combined path 16/17 are:

(19) ∘ E_s is presupposed
∘ E_s is not a process
∘ E_m and E_s are either both durative or both punctiliar

The third of these constraints will be eliminated when we examine paths (20), (21) and (22).

These next three readings will allow us to collapse the OVERLAPPING branch of Oversteegen's tree further:

(20) SIMULTANEOUS:OVERLAPPING:α IS INCLUDED IN β
When the time was right the judge arrived.
(21) SIMULTANEOUS:OVERLAPPING:α INCLUDES β
When the judge arrives, we'll have been waiting for several minutes. (Martin 4.47b)
(22) SIMULTANEOUS:OVERLAPPING:MERE OVERLAP
When John was in Boston, Mary was in Detroit.

Note that the three types of overlap here in conjunction with the two coextensive readings of the previously discussed senses of **when** enumerate all the possible temporal relations between E_s and E_m expressed by the following TTT formula for **when** (from [Oversteegen, 1993]):

(23) **when**: $\exists x \in \diamond S_m \exists y \in S_s^{max} : x = y$

In fact, we don't need to create different categories for all these temporal relations since they're all expressed by this one formula. We could, in fact, collapse all of these categories into one, but we will keep these three overlap categories separate from the two coextensive categories because cue words can distinguish between them:

(24) At the same moment when John arrived, Mary arrived.
(25) During the time when Mary was in Boston, John came to visit.

Oversteegen's constraints on the readings are shown below:

(20′) ∘ E_s is presupposed
∘ E_s is a process/state and E_m is a terminative event
∘ S_s^{max} bears no relation to **s**
∘ **s** may not be located between $\diamond S_m$ and S_s^{max}
(21′) ∘ E_s is presupposed
∘ E_s is a terminative event and E_m is a process/state
∘ deictic constraint
(22′) ∘ E_s is presupposed
∘ E_s is a process/state and E_m is a process/state
∘ deictic constraint

Because all combinations of aspectual classes are allowed (except processive E_s for English **when**) we can eliminate the constraints on aspect from the above, as well as the third constraint in (19). The constraints in (20′) concerning the position of **s** don't apply in English, and so can be eliminated as well.

The resulting set of constraints on paths 20/21/22 are as follows:

(26) ∘ E_s is presupposed
∘ E_s is not a process

The mixed consequential/temporal reading of **when** is illustrated in (27a):

(27) SUCCESSIVE:α POSTERIOR:CONSEQUENTIAL:OCCASIONAL
a. When I looked up the mouse ran. (Oversteegen 56)
b. ?When I looked up the water ran.

The OCCASIONAL/EXTENDED distinction was intended to distinguish between an E_m that occurs on one occasion and an E_m that continues on for a time. We have eliminated this distinction in our hierarchy, for reasons that will now be discussed.

Oversteegen's constraints on this path are as follows:

(27′) ∘ E_s is presupposed
∘ E_s is process/state
E_s is perspectivized
E_m contains an (implicit) agent
∘ deictic constraint

The reading is one in which there is an agent such as the mouse or at least an implicit agent in E_m, and E_s is "perspectivized" in the sense that the agent of E_m is the implicit observer of the subsentence event.

In English, this reading is possible when E_m is a telic as well, as in the following example:

(28) When I looked up, John turned his head away.

Furthermore, when E_m is telic there need not be an agent:

(29) When I looked up my hat fell off.

What's interesting about the Dutch reading is that the conditions that E_s be a process/state with an agent are sufficient conditions for the process/state to be coerced into a telic. (Why a telic can't occur in this position is a question that arises from this.) We can generalise over the possible aspectual classes possible in this reading in English by simply saying that E_s must be telic, and then allowing the processes of coercion turn a processive/stative E_s into a telic. We have then eliminated the following constraints:

(30) ∘ E_m is process/state
E_s is perspectivized
E_m contains an (implicit) agent

We can also eliminate the deictic constraint, which doesn't apply in English. We are left with the following constraints on this reading:

(31) ∘ E_s is presupposed
∘ E_s is not a process

The TTT formula isn't quite right for this successive reading since there is no overlap. The formula used for the previous readings is repeated below:

(32) **when**: $\exists x \in \diamond S_m \exists y \in S_s^{max} : x = y$

This can be represented in the lexical entry in terms of Allen's [1984] temporal relations in the following manner:

$$(33)\quad \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{SUBCAT} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{EVAL} & \boxed{2} \end{bmatrix} \end{bmatrix}_{vp\_max} \right\rangle \\ \text{MOD} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{IMAGE} & \boxed{5} \end{bmatrix} \end{bmatrix}_{vp\_max} \right\rangle \\ \text{TTT-CONDS} & \left\langle \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{2} \end{bmatrix}_{dur} , \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{5} \end{bmatrix}_{dur} \right\rangle \end{bmatrix} \end{bmatrix}$$

However, this must be modified for the reading in (27a), as follows:

$$(34)\quad \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{SUBCAT} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{EVAL} & \boxed{2} \end{bmatrix} \end{bmatrix}_{vp\_max} \right\rangle \\ \text{MOD} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{IMAGE} & \boxed{5} \end{bmatrix} \end{bmatrix}_{vp\_max} \right\rangle \\ \text{TTT-CONDS} & \left\langle \begin{bmatrix} \text{ARG1} & \boxed{2} \\ \text{ARG2} & \boxed{5} \end{bmatrix}_{meets} \right\rangle \end{bmatrix} \end{bmatrix}$$

A purely temporal reading of **when** is illustrated by the following sentence:

(35) SUCCESSIVE:ANTERIOR:PURELY TEMPORAL:NO OVERLAP
Mary was pulling at the door when John suddenly opened it.

This reading has the same TTT formula as the previous one, but it lacks the consequential reading. By employing this TTT formula, we can eliminate the NO OVERLAP constraint.

Oversteegen's constraints on path (35) are as follows:

(35′) ∘ E_s is usually a terminative event and E_m is usually a state or process
∘ strict ordering main sentence < subsentence
∘ deictic constraint

The constraint that E_s is usually a terminative event and E_m is usually a state or process is expected because, to get the strict ordering of $E_m < E_s$, E_s must do something to stop E_m, meaning that E_s must be either telic or inchoative and E_m must be an eventuality that is interruptible, namely something that has some duration. An eventive sentence is acceptable as the main sentence if it is in progressive form, indicating that the terminus has not been reached:

(36) The builders were building the bridge when the bomb destroyed their work.

We will incorporate these aspectual constraints into the lexical entry.

The strict placement of the subsentence after the main sentence is also necessary in English, as shown by the awkwardness of the following example:

(37) ?When John opened the door so suddenly, Mary had been pulling on it.

We can implement this by forcing the **when**-clause to attach at VP-level (i.e., to a *vp_max* with a non-empty subcat list) for this reading.

The single constraint on this reading is below:

(38) ∘ E_s is usually a terminative event and E_m is usually a state or process

The constraints can be summarised as follows:

(39) ∘ E_s is presupposed
∘ E_s is not a process, and
Either: ∘ The formula in (33) applies
or: ∘ The formula in (34) applies, and
  Either: ∘ There is a consequential relationship between E_s and E_m
  or: ∘ E_s is terminative and E_m is a state/process
   ∘ strict ordering main sentence < subsentence

The final version of the lexical entry is shown below:

$$
\begin{bmatrix}
\textsc{syn} & \begin{bmatrix}
\textsc{subcat} & \left\langle \begin{bmatrix}
\textsc{sem} & \boxed{3} \\
\textsc{tense} & \begin{bmatrix} \textsc{speech} & \boxed{1} \\ \textsc{eval} & \boxed{2} \end{bmatrix} \\
\textsc{aspect} & \boxed{6}\ \textit{(telic} \vee \textit{state)}
\end{bmatrix}_{\textit{vp\_max}} \right\rangle \\
\textsc{mod} & \left\langle \begin{bmatrix}
\textsc{subcat} & \boxed{4} \\
\textsc{tense} & \begin{bmatrix} \textsc{speech} & \boxed{1} \\ \textsc{image} & \boxed{5} \end{bmatrix} \\
\textsc{aspect} & \boxed{8}
\end{bmatrix}_{\textit{vp\_max}} \right\rangle
\end{bmatrix} \\
\textsc{sem} & \left(\begin{array}{l}
\begin{bmatrix}
\textsc{ttt-conds} & \left\langle \begin{bmatrix} \textsc{arg1} & \boxed{7} \\ \textsc{arg2} & \boxed{2} \end{bmatrix}_{\textit{dur}}, \begin{bmatrix} \textsc{arg1} & \boxed{7} \\ \textsc{arg2} & \boxed{5} \end{bmatrix}_{\textit{dur}} \right\rangle \\
\textsc{temporal\_restriction} & \textit{coextensive} \\
\textsc{presupposed} & \boxed{3}
\end{bmatrix} \vee \\
\begin{bmatrix}
\textsc{ttt-conds} & \left\langle \begin{bmatrix} \textsc{arg1} & \boxed{2} \\ \textsc{arg2} & \boxed{5} \end{bmatrix}_{\textit{meets}} \right\rangle \\
\textsc{temporal\_restriction} & \begin{array}{l} (\alpha\ \textit{posterior:consequential:yes} \\ \vee\ (\alpha\ \textit{anterior:consequential:no} \wedge \\ \textit{true}(\boxed{6} \wedge \textit{telic}) \wedge \textit{true}(\boxed{8} \wedge \textit{atelic})) \\ \wedge\ \textit{true}(\boxed{4} \wedge \textit{nonempty\_list})) \end{array} \\
\textsc{presupposed} & \boxed{3}
\end{bmatrix}
\end{array} \right)
\end{bmatrix}
$$

The two possible semantic representations reflect that two TTT formulae are possible. In the second disjunct of the semantic representations the contents of the TEMPORAL_RESTRICTION slot reflect that when the formula in (34) applies there is either a consequential relationship (α *posterior:consequential:yes*) or there is no consequential relationship and the subsentence expresses a telic (*true(* $\boxed{6}$ $\wedge$ *telic)*), the main sentence expresses a state/process (*true(* $\boxed{8}$ $\wedge$ *atelic)*) and the subsentence follows the main sentence, enforced by having the **when**-clause attach at VP-level (true($\boxed{4}$ $\wedge$ nonempty_list)). (The CUF operator *true* succeeds if its argument(s) are unifiable.)

5.2 *While*

While can be reached through three branches of Oversteegen's tree and through two of our tree. We have combined the following two readings:

(40) SIMULTANEOUS:COEXTENSION:DURATION:NOT ITERATIVE
While we were waiting, we felt confident. (Martin 4.28)
While we stand and wait the judge handles the dogs. (Martin 4.43b)
(41) SIMULTANEOUS:COEXTENSION:DURATION:ITERATIVE
While I kicked the car's tyre, John checked the trunk.

Instead of distinguishing between iterated events and non-iterated ones, we can rely on an analysis of coercion to refer to the iterated event as a process, thus reducing these constraints to a simple determination of which aspectual classes are acceptable. Oversteegen's constraints on these readings are shown below:

(40′) ∘ $\diamond \mathrm{S}_m$ and S_s^{max} are comparable
∘ E_s is presupposed
∘ S_s^{max} bears no relation to **s**
(41′) ∘ E_s is presupposed
∘ E_s is a process/state and E_m is a terminative event
∘ S_s^{max} bears no relation to **s**

The only difference between the two readings is that path (40) requires $\diamond \mathrm{S}_m$ and S_s^{max} to be comparable in length while path (41) requires E_s to be a process/state and E_m a terminative event. E_m must be a terminative event in order for it to have an iterative reading, however, so we can let our coercion procedures take care of this requirement and eliminate it from the constraints on the paths. When a terminative event is iterated, it is coerced into a process, so the constraint will now require that E_s be process/state and E_m a process.

But what are the aspectual restrictions on E_s and E_m in English? The following examples show that E_s must be durative but E_m can be of any aspectual class and can be either durative or punctiliar:

(42) Martha was in Brazil while John was in France.
(43) Martha arrived while John was in France.
(44) He threw himself on the rudder while we shot past the boat's stern.
(45) ?Martha was in Brazil while John arrived.
(46) ?Martha entered the room while John appeared.

We can implement the constraint on E_s via the lexical entry for **while**. The constraint that E_s and E_m must be comparable in length doesn't need to be enforced because the formula for **while**, shown below, allows us to generalise over the cases in which E_m is punctiliar and cases in which it is durative:

(47) **while**: $\forall x \in \diamond S_m \exists y \in S_s^{max} : x = y$

This formula says that the evaluation points for the main sentence event are a subset of the evaluation points for the subsentence event. If E_m is punctiliar it will be included in E_s and if not it will be coextensive with E_s. Given this conclusion, we could collapse Oversteegen's third path for **while** with these others:

(48) SIMULTANEOUS:OVERLAPPING:IS INCLUDED
While we waited the judge arrived. (Martin 4.45b)

Her constraints on path (48) are as follows:

(48′) ∘ $\diamond S_m$ and S_s^{max} are comparable
∘ E_s is presupposed
∘ E_s is a process/state
∘ S_s^{max} bears no relation to **s**
∘ **s** may not be located between $\diamond S_m$ and S_s^{max}

If we treat the aspectual specifications lexically as discussed above, we can collapse these three readings. However, because cue phrases can distinguish between a reading in which E_s includes E_m and the coextensive readings, as shown below, we will keep this third category separate in the hierarchy:

(49) While Mary was working on the exam Martha came in and completed it in two minutes.

There is one problem that should be mentioned here, and that is that some events which one would tend to lexically mark as punctual can have a durative interpretation, as in (50):

(50) Martha waited on the platform while the train arrived.

The event described by *arrive* is generally treated as punctual, but it can be understood as durative in this example. We will treat such examples as cases in which the punctual event has been coerced into a durative one, but, although this a reasonable solution, it is perhaps not what is truly going on in such cases. Intuitively, there is something that we know about the arrival of trains that allows us to understand them as durative events; a more realistic but computationally intractable solution is that our knowledge of the world and how things work is what allows us to interpret the event as durative.

There are two further constraints to be discussed. The first, shown below, is placed on all three readings:

(51) ∘ S_s^{max} bears no relation to **s**

In English, the tense determines the relationship between S_s^{max} and **s**, so we can eliminate this constraint. The second constraint, shown below, cannot hold because there is never a time interval between $\diamond S_m$ and S_s^{max}:

(52) ∘ **s** may not be located between $\diamond S_m$ and S_s^{max}

The final constraints are below:

(53) ∘ E_s is presupposed
∘ E_s is durative

$$
\begin{bmatrix}
\text{SYN} & \begin{bmatrix}
\text{SUBCAT} & \left\langle {}_{\textit{vp\_max}}\begin{bmatrix} \text{SEM} & \boxed{3} \\ \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{EVAL} & \boxed{2} \end{bmatrix} \\ \text{DURATIVITY} & \textit{durative} \end{bmatrix} \right\rangle \\
\text{MOD} & \left\langle {}_{\textit{vp\_max}}\begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{IMAGE} & \boxed{5} \end{bmatrix} \end{bmatrix} \right\rangle \\
\text{TTT-CONDS} & \left\langle {}_{\textit{dur}}\begin{bmatrix} \text{ARG1} & \boxed{5} \\ \text{ARG2} & \boxed{2} \end{bmatrix} \right\rangle
\end{bmatrix} \\
\text{SEM} & \begin{bmatrix} \text{TEMPORAL\_RESTRICTION} & \textit{simultaneous} \\ \text{PRESUPPOSED} & \boxed{3} \end{bmatrix}
\end{bmatrix}
$$

5.3 *Before*

Before can be reached through five branches of Oversteegen's tree and through two of our tree. Consider first the three consequential readings described by Oversteegen:

(54) SUCCESSIVE:ANTERIOR:CONSEQUENTIAL:OCCASIONAL:POSITIVE
We had to install a new battery **before** the car started. (Oversteegen 101a)
(55) SUCCESSIVE:ANTERIOR:CONSEQUENTIAL:OCCASIONAL:NEGATIVE:NOT REALIZED
Mary left **before** the police caught up to her.
(56) SUCCESSIVE:ANTERIOR:CONSEQUENTIAL:OCCASIONAL:NEGATIVE:(NOT) REALIZED
Mary left **before** anyone saw her.

Oversteegen's constraints for these readings are shown below:

(54′) ∘ E_s is presupposed
∘ E_m leads to E_s
∘ E_m contains deontic marker
(55′) ∘ E_s is not presupposed
∘ E_s is expected (default from context) or intended
∘ E_s is evaluated (positively or negatively)
∘ E_s does not occur
∘ E_s contains epistemic marker (or it can be added)
∘ E_m is new
(56′) ∘ E_s is not presupposed
∘ E_s is expected (default from context) or intended
∘ E_s is evaluated (positively or negatively)
∘ negative polarity marker present

We can treat the causal reading between E_m and E_s in the sentences of path (54) in a planning module, by restating the constraint to say that E_m is a prerequisite of the goal E_s. We can then relate the presence of the deontic marker to the rule that one is obliged to complete the prerequisites of a goal before the goal can be achieved. The sentences of path (55) can also be related to plans in the sense that one of the prerequisites of the goal E_s has not been met because E_m has occured. This avoidance of the goal E_s on the part of another agent explains the (potential) presence of the epistemic marker. E_s will be evaluated as a positive goal for the agent of the subsentence and a negative goal for the agent of the main sentence.

The readings in (55) and (56) can be combined in English; the difference is that the former can contain an epistemic marker and the latter contains a negative polarity marker, but note from the following examples that the former can also contain a negative polarity marker and the latter an epistemic marker in English:

(57) Mary left before any police caught/could catch up to her.
(58) Mary left before anyone could see her.

The planning module will specify which modals are associated with various planning moves. We will not attempt to specify a planning module, however, but we will indicate the association of these readings with planning by means of the type PLAN_SITUATION.

A final constraint that needs to be discussed is that E_m is new. This means that E_m is not part of the common ground, i.e., not presupposed. In this case, we simply add the condition that E_m occured to the DRS as usual, so no special constraint is needed.

The next two readings of **before** are purely temporal, both indicating that E_m precedes E_s:

(59) SUCCESSIVE:ANTERIOR:PURELY TEMPORAL:NO OVERLAP
Before we won that competition we'd won several others. (Martin 4.34)
Before the judge handled the dogs we'd tabled them. (Martin 4.51b)

(60) SUCCESSIVE:ANTERIOR:PURELY TEMPORAL:OVERLAP ALLOWED
John was in Boston **before** Mary arrived.

Oversteegen's constraints for these paths are as follows:

(59′) ∘ E_s is presupposed
∘ terminative E_s

(60′) ∘ E_s is presupposed, and
either: ∘ E_s is a process and
∘ E_s has an inchoative marker or:
E_m expresses time measurement or:
E_s is put in Perfect
or: ∘ E_s is terminative
∘ E_m is a process/state

We can collapse these two readings by relying on the formula for **before**:

(61) $\exists x \in \diamond S_m \forall y \in S_s^{max} : x < y$

This formula states that there is at least one evaluation point for the main sentence event that precedes all evaluation points for the subsentence event. This allows overlap when E_m is atelic but not when it is telic, which corresponds to the English data:

(62) John was in Boston **before** Mary was.
(63) John was in Boston **before** Mary arrived.
(64) John arrived in Boston **before** Mary was there.
(65) John arrived in Boston **before** Mary did.

The final set of constraints which we will adopt is shown below:

(66) Either: ∘ E_s is presupposed
or: ∘ PLAN_SITUATION:*goal_conflict*

$$
\begin{bmatrix}
\text{SYN} & \begin{bmatrix}
\text{SUBCAT} & \left\langle \begin{bmatrix} \text{SEM} & \boxed{3} \\ \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{EVAL} & \boxed{2} \end{bmatrix} \end{bmatrix}_{\mathit{vp\_max}} \right\rangle \\
\text{MOD} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{IMAGE} & \boxed{5} \end{bmatrix} \end{bmatrix}_{\mathit{vp\_max}} \right\rangle \\
\text{TTT-CONDS} & \left\langle \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{5} \end{bmatrix}_{\mathit{dur}}, \begin{bmatrix} \text{ARG1} & \boxed{2} \\ \text{ARG2} & \boxed{7} \end{bmatrix}_{\mathit{bef}} \right\rangle
\end{bmatrix} \\
\text{SEM} & \begin{bmatrix}
\text{TEMPORAL\_RESTRICTION} & (\alpha\ \mathit{anterior{:}consequential{:}no} \vee \mathit{true}(\mathit{goal\_subsumption} \wedge \boxed{4})) \\
\text{PRESUPPOSED} & \boxed{3} \\
\text{PLAN} & \begin{bmatrix} \text{PLAN\_SITUATION} & \boxed{4} \end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

$$
\vee
\begin{bmatrix}
\text{SYN} & \begin{bmatrix}
\text{SUBCAT} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{EVAL} & \boxed{2} \end{bmatrix} \end{bmatrix}_{\mathit{vp\_max}} \right\rangle \\
\text{MOD} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{IMAGE} & \boxed{5} \end{bmatrix} \end{bmatrix}_{\mathit{vp\_max}} \right\rangle \\
\text{TTT-CONDS} & \left\langle \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{5} \end{bmatrix}_{\mathit{dur}}, \begin{bmatrix} \text{ARG1} & \boxed{2} \\ \text{ARG2} & \boxed{7} \end{bmatrix}_{\mathit{bef}} \right\rangle
\end{bmatrix} \\
\text{SEM} & \begin{bmatrix}
\text{TEMPORAL\_RESTRICTION} & \begin{bmatrix} \text{CONSEQUENTIAL} & \mathit{yes} \end{bmatrix}_{\alpha\ \mathit{anterior}}
\end{bmatrix} \\
\text{PLAN} & \begin{bmatrix} \text{PLAN\_SITUATION} & \mathit{goal\_conflict} \end{bmatrix}
\end{bmatrix}
$$

5.4 *After*

After can be reached through only one branch of Oversteegen's tree and also only through one of our tree:

(67) SUCCESSIVE:α POSTERIOR:PURELY TEMPORAL
After we walk the ring with our dogs we just wait. (Martin 4.48b)

Oversteegen's constraints for path (67) are as follows:

(67′) ∘ E_s is presupposed
∘ If E_s or E_m are process/state, the subsentence is in Pluperfect

The second constraint isn't applicable in English, as the example above shows.

The TTT formula for **after** is below:

- $\forall x \in \diamond S_m \forall y \in S_x^{max} : x < y$

The final representation is as follows:

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{SUBCAT} & \left\langle \begin{bmatrix} \text{SEM} & \boxed{3} \\ \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{EVAL} & \boxed{2} \end{bmatrix} \end{bmatrix}_{vp\_max} \right\rangle \\ \text{MOD} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{IMAGE} & \boxed{5} \end{bmatrix} \end{bmatrix}_{vp\_max} \right\rangle \\ \text{TTT-CONDS} & \left\langle \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{5} \end{bmatrix}_{dur}, \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{2} \end{bmatrix}_{bef} \right\rangle \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{TEMPORAL\_RESTRICTION} & \begin{bmatrix} \text{CONSEQUENTIAL} & no \end{bmatrix}_{\alpha\ posterior} \\ \text{PRESUPPOSED} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

5.5 *Until*

Until can be reached through only one branch of Oversteegen's tree and also only through one of our tree.

(68) SUCCESSIVE:ANTERIOR:CONSEQUENTIAL:EXTENDED
Until he arrived, we weren't sure what to do. (Martin 4.39)
We waited **until** the judge told us to get the best out of our dogs. (Martin 4.54)

Oversteegen's constraints for path (68) are as follows:

(68′) ∘ E_s is presupposed
∘ context/speech situation $\longrightarrow$ initial boundary E_m

These constraints hold in English as well, along with the constraint that E_m must be atelic, as in the following example:

(69) a. **Until** he arrived, we knew what to do.
b. ?**Until** he arrived we decided what to do.

However, that the context/speech situation $\longrightarrow$ initial boundary E_m can be eliminated because it is already expressed by the TTT formula, below:

- $\forall x \in S \forall y \in S_s^{max} : x < y \rightarrow x \in \diamond S_m$

The final representation is below:

$$\begin{bmatrix}
\text{SYN} & \begin{bmatrix}
\text{SUBCAT} & \left\langle \underset{\mathit{vp_max}}{\begin{bmatrix} \text{SEM} & \boxed{3} \\ \text{TENSE} & \begin{bmatrix}\text{SPEECH} & \boxed{1}\\ \text{EVAL} & \boxed{2}\end{bmatrix}\end{bmatrix}} \right\rangle \\
\text{MOD} & \left\langle \underset{\mathit{vp_max}}{\begin{bmatrix} \text{TENSE} & \begin{bmatrix}\text{SPEECH} & \boxed{1}\\ \text{IMAGE} & \boxed{5}\end{bmatrix} \\ \text{ASPECT} & \mathit{atelic}\end{bmatrix}} \right\rangle \\
\text{TTT-CONDS} & \left\langle \underset{\mathit{meets}}{\begin{bmatrix}\text{ARG1} & \boxed{5}\\ \text{ARG2} & \boxed{2}\end{bmatrix}} \right\rangle
\end{bmatrix} \\
\text{SEM} & \begin{bmatrix}
\text{TEMPORAL_RESTRICTION} & \underset{\alpha\ \mathit{anterior}}{\begin{bmatrix}\text{CONSEQUENTIAL} & \mathit{yes}\end{bmatrix}} \\
\text{PRESUPPOSED} & \boxed{3}
\end{bmatrix}
\end{bmatrix}$$

5.6 *Since*

Since can be reached through four branches of Oversteegen's tree and through only one of ours. The four branches are given below:

(70) SUCCESSIVE:POSTERIOR:CONSEQUENTIAL:EXTENDED:NO OVERLAP:NOT ITERATIVE
Since I saw you last I've entered the competition.
Since we entered the competition last year we haven't won. (Martin 4.49b)
(71) SUCCESSIVE:POSTERIOR:CONSEQUENTIAL:EXTENDED:NO OVERLAP:ITERATIVE
Since we entered the competition last year we've won repeatedly.
(72) SUCCESSIVE:POSTERIOR:CONSEQUENTIAL:EXTENDED:OVERLAP ALLOWED:NOT ITERATIVE
The smurfs have grown to be less popular since they have been recommending a brand of fuel. (adapted from (Oversteegen 120a))
(73) SUCCESSIVE:POSTERIOR:CONSEQUENTIAL:EXTENDED:OVERLAP ALLOWED:ITERATIVE
The smurfs have made frequent appearances since they have been sleeping shorter hours.

Oversteegen's constraints on these paths are shown below:

(70′) ∘ E_s is presupposed
∘ context/speech situation $\longrightarrow$ final boundary E_m
∘ $\diamond S_s < \mathbf{s}$ (forces the tense constraint to work)
(71′) ∘ E_s is presupposed
∘ E_m is terminative
∘ context/speech situation $\longrightarrow$ final boundary E_m
∘ $\diamond S_s < \mathbf{s}$
(72′) ∘ E_s is presupposed
∘ E_s is a process
∘ context/speech situation $\longrightarrow$ final boundary E_m
∘ $\diamond S_s < \mathbf{s}$
(73′) E_s is presupposed
∘ E_m is terminative
∘ context/speech situation $\longrightarrow$ final boundary E_m
∘ $\diamond S_s < \mathbf{s}$

The distinction between iterative and non-iterative can be eliminated as we have done previously, and absorbed by our representation of the coercion processes.

The constraint $\diamond S_s < \mathbf{s}$ also holds in English, but can be implemented in terms of a lexical constraint on the tense of the main sentence; in English the main sentence must be in perfect tense.

The final constraint, that the context/speech situation $\longrightarrow$ final boundary E_m, holds in English when E_m is atelic, but not when it is telic, as shown by the examples below:

(74) John has been in Boston since he was born.
(75) John has visited Boston since he moved to Europe.

Sentence (75) has the interpretation that there was an instance of John visiting Boston between speech time and the time of E_s. We can move this constraint into the lexicon.

We haven't treated the completely nontemporal interpretation of **since**, as in:

(76) Since John said Boston was nice I decided to visit it.

Note that in the temporal version α must be in the perfect tense.

The final constraints are below:

(77) ∘ E_m is presupposed
∘ The main sentence is in perfect tense
∘ Either: E_m is atelic, and
∘ The following TTT formula holds:
$\exists x \in S_s^{max} \forall y \in S : x < y \rightarrow y \in \diamond S_m$
or: ∘ E_m is telic and
The following TTT formula holds:
$\forall x \in S_s^{max} x \in \diamond S_m$

$$\begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{SUBCAT} & \left\langle \begin{bmatrix} \text{SEM} & \boxed{3} \\ \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{EVAL} & \boxed{2} \end{bmatrix} \end{bmatrix}_{vp\_max} \right\rangle \\ \text{MOD} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{IMAGE} & \boxed{5} \\ \text{PERF} & yes \end{bmatrix} \\ \text{ASPECT} & atelic \end{bmatrix}_{vp\_max} \right\rangle \\ \text{TTT-CONDS} & \left\langle \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{5} \end{bmatrix}_{dur}, \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{2} \end{bmatrix}_{meets}, \begin{bmatrix} \text{ARG1} & \boxed{2} \\ \text{ARG2} & \boxed{1} \end{bmatrix}_{meets} \right\rangle \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{TEMPORAL\_RESTRICTION} & \begin{bmatrix} \text{CONSEQUENTIAL} & yes \end{bmatrix}_{\alpha\ posterior} \\ \text{PRESUPPOSED} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

$$\vee \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{SUBCAT} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{EVAL} & \boxed{2} \end{bmatrix} \end{bmatrix}_{vp\_max} \right\rangle \\ \text{MOD} & \left\langle \begin{bmatrix} \text{TENSE} & \begin{bmatrix} \text{SPEECH} & \boxed{1} \\ \text{IMAGE} & \boxed{5} \\ \text{PERF} & yes \end{bmatrix} \\ \text{ASPECT} & telic \end{bmatrix}_{vp\_max} \right\rangle \\ \text{TTT-CONDS} & \left\langle \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{5} \end{bmatrix}_{dur}, \begin{bmatrix} \text{ARG1} & \boxed{7} \\ \text{ARG2} & \boxed{2} \end{bmatrix}_{bef}, \begin{bmatrix} \text{ARG1} & \boxed{2} \\ \text{ARG2} & \boxed{1} \end{bmatrix}_{bef} \right\rangle \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{TEMPORAL\_RESTRICTION} & \begin{bmatrix} \text{CONSEQUENTIAL} & yes \end{bmatrix}_{\alpha\ posterior} \end{bmatrix} \end{bmatrix}$$

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