The Progressive and the Imperfective Paradox

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Abstract

Formal semantics constitutes the framework of the research presented here, and the aim is to provide a solution to the imperfective paradox; i.e. explain why "Max was running" entails "Max ran", but "Max was running home" does not entail "Max ran home". This paper is divided into two parts. In Part I we evaluate what I will call the *Eventual Outcome Strategy* for solving the imperfective paradox. This strategy is commonly used (Dowty 1979, Hinrichs 1983, Cooper 1985), and is highly intuitively motivated. I will show, however, that the formulations of the intuitions give rise to conflicts and tensions when it comes to explaining the natural language data. In Part II we offer a new approach to tackle the imperfective paradox that overcomes the problems with the Eventual Outcome Strategy.

Aims

The research pursued here fits into a programme the aim of which is to supply the formal semantics of natural language. The assumption underlying this venture is that the meaning of linguistic expressions can be characterised by defining all their possible logical consequences. Our aim is to supply a solution to a problem known as the "imperfective paradox". According to intuitions, sentence (1) entails (2), but no entailment holds between (3) and (4).

(1) Max was running a business

(2) Max ran a business

(3) Max was building a house

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(4) Max built a house

Since (1) and (3) would seem to have similar logical forms, they ought to have similar entailments. A solution to the imperfective paradox must explain why this is not so.

The imperfective paradox has serious implications for more general questions concerning natural language, for example the relationship between syntax and semantics. The progressive involves a uniform syntactic operation, and so from the perspective of formal semantics, one would expect it to be related to a uniform semantic operation. But (1) and (3) have different semantic import. The problem is: how can the uniformity of the progressive in syntax be squared with its semantic 'irregularity'?

To solve the imperfective paradox, two tasks must be achieved. First, we must characterise the semantic distinction between (2) and (4), which is revealed in natural language by their different behaviours with the progressive. Second, we must define the semantics of the progressive so that it is sensitive to this distinction and so results in a solution to the imperfective paradox.

This paper is divided into two parts. In Part I we evaluate what I will call the *Eventual Outcome Strategy* for defining the progressive. This strategy is commonly used; it has been deployed by Dowty (1979), Hinrichs (1983) and Cooper (1985). The strategy is highly intuitively motivated. We will show, however, that the formulations of the intuitions give rise to conflicts and tensions when it comes to explaining the natural language data, and so it cannot be used as part of a solution to the imperfective paradox. In Part II we offer a new approach to tackle the imperfective paradox. This new approach overcomes the problems with the Eventual Outcome Strategy.

Part I

The Eventual Outcome Strategy

1 The Motivation for the Eventual Outcome Strategy

The Eventual Outcome Strategy gives us a way of defining the semantics of the progressive. To see how the strategy is motivated, let us examine from an intuitive perspective what criteria are used to decide whether a progressive sentence is true. To start with, are there any criteria that one may apply *directly* to the current state of affairs, to discover whether that state of affairs makes a progressive sentence true? Consider sentence (5).

(5) Max is winning the race

It seems that such criteria would be difficult to describe. The states of affairs which make sentence (5) true could amount to almost anything. (5) may be true when Max is ahead, or when he is second but the athlete in first place has just twisted his ankle. If the race is happening over two days with a period of rest overnight, then (5) may be true even if Max is asleep.

What property, if any, do all these states of affairs have, that can be regarded as the property making the progressive sentence true? The puzzle is: Given the wealth of states of affairs that can be regarded as an instance of (5), it seems that a search for a common property among them would prove fruitless. However, there is the following strong intuition: (5) is true just in case there is something going on now, *whatever* that is, such that if it were to continue uninterrupted, then the outcome would be that Max is the winner of the race.

This intuition indicates that the common property of all the progressive states of affairs may not be found by looking at the state only at the current time; instead one must investigate the *outcome* of the state of affairs. This may offer a strategy to yield the formal semantics of the progressive. The truth conditions placed by the semantic definition of the progressive on the current state of affairs should not be conditions that concern what is going on now, but must be conditions on the *eventual outcome* of what is going on now. I call this strategy for defining the progressive the *Eventual Outcome Strategy*.

To get a clearer picture of what the Eventual Outcome Strategy involves, let's see how it would relate sentences (6) and (7).

(6) Max was winning the race

(7) Max won the race

Intuitively, (7) refers to a process which leads to a culmination. (6) refers to that process, but it does not assert that the culmination of the process occurred. The idea behind the Eventual Outcome Strategy is to define the semantics of (6) and (7) so that they do not place conditions directly on what the process leading to the culmination consists of. For example, the semantics of these sentences will not talk of whether Max had a good start to the race, whether he was ahead at the half way stage, and so on. Instead, the process is characterised in the semantics of the progressive in terms of the culmination: *Whatever* the process is, *if* it were to continue uninterrupted, then it *would* lead to the culmination. So the definition of the progressive under the Eventual Outcome Strategy essentially involves modality of the 'counterfactual' kind.

We have seen that the process (5) refers to is characterised in the Eventual Outcome semantics of the progressive in terms of the culmination, plus some appropriate sense of modality. Given this semantics, any formulation of the strategy must fulfil two tasks. First, it must offer a semantic account of the culmination that the process would lead to. Second, it must offer an account of the modality in the definition of the progressive; i.e. an explanation of the phrase "if the process were to continue uninterrupted".

Our objective is to test whether the Eventual Outcome Strategy can be formulated, and if so, establish how the formulation would deal with the two tasks at hand.

2 The Consequences of the Eventual Outcome Strategy

In order to have a perspective from which to test the Eventual Outcome Strategy, I will now set up a question that concerns the consequences of formulating it.

Consider the following situation: suppose that Max is running in a race of four laps. Suppose he is ahead at the start of the third lap and running the fastest. Then according to intuitions, sentence (5) is true at this time.

(5) Max is winning the race

Now suppose that at the start of the fourth lap, Max has fallen behind in the race. He is now last, and it looks as though only a miracle could bring him victory. So according to intuitions, sentence (5) is now false. Suppose that, despite everything, Max surges forward half way through the fourth lap to gain first position again. Then according to intuitions (5) is true once again. Now suppose that Max crosses the finish line in first place to win the race. Then, since according to intuitions the above situation is possible, *The Scenario* (given in figure 1) must depict a possible state of affairs.

Figure 1: *The Scenario*

The question now is: when is sentence (8) true in this state of affairs?

(8) Max wins the race

(8) must be true at some time in *The Scenario*, since Max does actually win the race. Suppose that (8) is true with respect to a period of time, to reflect the idea that (8) is about a process that goes on over a period of time which leads to a culmination. Then our question is: will the formulation of the Eventual Outcome Strategy allow this period to contain *all* the times depicted in figure 1, yielding the temporal structure in figure 2, labelled *The Test Structure*? Clearly, the state of affairs depicted in figure 1, which any

Figure 2: The Test Structure

satisfactory semantic theory must deem as possible, is related to the state of affairs depicted in figure 2, and just how they are related in the theory depends on the semantics of the progressive and the semantics of (8). Our puzzle is: will an Eventual Outcome theory *allow* for a semantic interpretation of the progressive and (8) that describes the state of affairs depicted in figure 2? In the rest of this chapter, I will define the state of affairs depicted in figure 2 as *consistent* if there is a semantic interpretation of the progressive and (8) that describes that state of affairs, and *inconsistent* if there is no such semantic interpretation. So our puzzle can be stated in another way: will an Eventual Outcome theory establish the state of affairs depicted in figure 2: *The Test Structure* as consistent or as inconsistent?

I will examine whether The Test Structure is consistent in Dowty's (1979) theory that formulates the Eventual Outcome Strategy. We have seen that an Eventual Outcome semantics of the progressive defines the semantics of sentence (5) purely in terms of the culmination, plus some appropriate notion of modality. I will argue that one can obtain an appropriate notion of *modality* only if one establishes that the state of affairs depicted in The Test Structure is *inconsistent*. On the other hand, I will argue that if one is to characterise (5) in terms of the culmination, then one must allow The Test Structure to be *consistent*. This exposes a tension in the two tasks that must be tackled in formulating the Eventual Outcome Strategy. I will show in this paper that this argument applies to Dowty's (1979) formulation of the Eventual Outcome Strategy, and in Lascarides (1988) I showed that the argument also carries over to the other two theories that formulate the strategy; that of Cooper (1985) and Hinrichs (1983). I will conclude from this that even though the Eventual Outcome Strategy is highly intuitively motivated, it is ultimately untenable.

It is important to realise that our argument against the Eventual Outcome Strategy is independent of the intuitions one might have concerning whether The Test Structure should be consistent or inconsistent. There seems to be something highly counterintuitive in allowing for a semantic interpretation of (8) and (5) that describes the state of affairs depicted in figure 2. One feels that sentences (8) and (5) should refer to the same process, and so the period of time over which (8)'s process goes on should not contain times at which (5) is false. And yet in The Test Structure, (5) *is* false in that period. So according to intuitions, The Test Structure should be inconsistent. However, it must be stressed that our argument against the Eventual Outcome Strategy is not based on this intuition. The argument is based on something slightly stronger. *Any* formulation of the Eventual Outcome Strategy must account for The Test Structure as consistent or as inconsistent. I will argue that *either way*, the formulation fails. In each case, the reasons it fails are independent of the intuition that The Test Structure should be inconsistent.

Parsons (1989) and Vlach (1981) mention some problems with Dowty's analysis of the progressive, but the status of their criticisms is unclear as their arguments against Dowty's theory are not formalised. It is therefore difficult to see if the criticisms are valid, let alone evaluate whether they stem from Dowty's particular formulation of the theory or from his basic approach. To avoid these problems, we aim for an argument against Dowty's strategy for defining the progressive couched in *formal* terms.

3 Dowty's Formulation of the Eventual Outcome Strategy

Before we look at Dowty's Eventual Outcome definition of the progressive, let us look at how he analyses non-progressive sentences like (8), for the progressive will be defined in terms of these.

(8) Max wins the race

Dowty represents the semantics of sentences like (8) by formulating Vendler's (1967) classification of aspect into a semantic framework. Vendler divided linguistic expressions into four aspectual classes, according to their different temporal behaviours, and provided metaphysical descriptions of these classes which were meant to explain their different temporal behaviours.

Vendler's classification consists of four aspectual classes; there are activity sentences like (2), accomplishment sentences like (4), achievement sentences like (8) and stative sentences like (9).

(2) Max ran a business

(4) Max built a house

(9) Max is insane

Activities are processes in time, 'most' parts of which are themselves a process of the same type; e.g. most parts of Max running a business are themselves instances of Max running a business. In contrast, accomplishments are more than processes; they essential involve a 'culmination' or 'conclusion'. Thus any part of an accomplishment which doesn't include the culmination cannot be an accomplishment of the same type. Achievements also invoke a culmination, but they differ from accomplishments in that they do not necessarily invoke a 'prior' process leading to the culmination. States can occur over a period of time, but they are not processes.

In formulating Vendler's distinctions between the aspectual classes, Dowty achieves the first goal in solving the imperfective paradox that we stated earlier; distinguishing the semantics of (2) and (4).

Dowty proposes his theory of aspect in an *interval-based* semantics: the truth of a sentence is defined relative to an interval of time. According to Vendler, an accomplishment occurs over an interval of time since the process it describes goes on over an extended period. One can capture this using Dowty's interval-based framework. If (4) is true at an interval I, then there is an interval J earlier than I where the tenseless sentence "Max build a house" is true; this reflects the idea that the accomplishment occurs over the interval J.

Dowty's objective is to interpret all non-stative sentences as combinations of statives with explicitly interpreted operators. To achieve this, he postulates a single class of predicates, which are the *stative predicates* such as "is insane". The logical form of the stative sentence (9) is the atomic formula (9a).

(9) Max is insane

(9a) $insane'(max')$

Dowty's analysis of statives is *homogeneous*, i.e. if (9a) is true at an interval I, then it is true at all subintervals of I. This reflects the intuition that any part of a state is itself a state of the same type. In other words, every part of Max being insane is itself an instance of Max being insane. Activities, accomplishments and achievements are all derived from statives by the application of certain operators and connectives, which yield *heterogeneous* interpretations of these classes: i.e. an activity, achievement or accomplishment sentence may be true at an interval I and false at subintervals of I. This reflects the intuition that certain parts of an activity, achievement or accomplishment are not themselves an activity, achievement or accomplishment of the same type. In other words, not all parts of Max running are themselves instances of Max running; not all parts of Max building a house are themselves instances of Max building a house; and so on.

4 Dowty's Semantic Interpretation of Achievements

We will be testing the Eventual Outcome Strategy using sentence (8).

(8) Max wins the race

(8) denotes an achievement, and Dowty observes, in agreement with Kenny (1963), that an achievement always involves the coming about of a particular *state of affairs*. In order to capture this observation, Dowty represents achievement sentences with the aid of the operator $BECOME$. The logical form of tenseless achievement sentences is given by (10), where ϕ denotes the state of affairs once the achievement is completed.

(10) $[BECOME\phi]$

For example, the tenseless achievement sentence (11) will have the logical form (11a), where $winner'(max', race')$ represents the state that Max is the winner of the race.[1]

(11) Max win the race

(11a) $[BECOME(winner'(max', race'))]$

The truth conditions for $[BECOME\phi]$, where ϕ is a formula, are given below:

- *The Truth Conditions for BECOME*
  $[BECOME\phi]$ is true at the interval-world index $\langle I, w\rangle$ if and only if there is an interval J containing the initial bound of I such that $\neg\phi$ is true at $\langle J, w\rangle$ and there is an interval K containing the final bound of I such that ϕ is true at $\langle K, w\rangle$.

The truth of the sentence $[BECOME\phi]$ requires the temporal structure in figure 3. Note that achievement sentences are false at all *minimal* intervals (i.e. intervals with no proper subintervals), where a minimal interval is a singleton set $\{t\}$ (for Dowty views intervals as connected sets over the reals). For if $[BECOME\phi]$ is true at $\{t\}$, then both ϕ and $\neg\phi$ must be true at $\{t\}$. Therefore $[BECOME\phi]$ is false at all minimal intervals for all ϕ. Vendler claims that achievements are punctual, and yet Dowty's achievements are *false* at all minimal intervals. Therefore Dowty's analysis of achievement sentences does not conform

[1] For the sake of simplicity, nouns such as *house* and *race* will be represented by name constants. This simplification does not have any bearing on our purposes here.

Figure 3: *The Temporal Structure for BECOME*

exactly to Vendler's metaphysical description of them.[2] The truth value of $[BECOME\phi]$ at the interval I is determined solely by what goes on at the endpoints of I. No conditions are placed on what goes on *during* the interval I. Thus Dowty avoids defining *directly* in the semantics of (8) what constitutes the process that leads to Max being the winner of the race. This is an essential part of the Eventual Outcome Strategy. There is an abundance of states of affairs that may correspond to the coming about of the target ϕ, and Dowty avoids describing these.

Clearly, it is not just any state of affairs that deserves to be regarded as the process that leads to the goal. The innovation in the Eventual Outcome Strategy is that the definition of the progressive in *modal* terms will reveal when the process goes on.

4.1 Dowty's Analysis of the Progressive

Dowty interprets the progressive as a mixed modal-temporal operator. Its definition is the following:

- $[PROG\phi]$ is true at an index $\langle I, w\rangle$ if and only if there is an interval I' such that I is contained in I' and I is not a final subinterval of I', and for all the worlds $w' \in Inr(\langle I, w\rangle)$, ϕ is true at $\langle I', w'\rangle$.

The primitive function Inr is defined as part of the model. It is a two-placed function, taking an interval and a world as its arguments. The evaluation of $Inr(\langle I, w\rangle)$ gives the *inertia worlds* at $\langle I, w\rangle$, and these characterise the 'natural course of events' at $\langle I, w\rangle$. Intuitively, $Inr(\langle I, w\rangle)$ contains all worlds w' that (a) are like the world w up to and including the interval I, and (b) include the natural course of events with respect to the situation in w at I. In other words, an inertia world can be thought of as a world in which nothing *unexpected* happens. So the above definition of $PROG$ states that $[PROG\phi]$ is true only if ϕ is true in every world where nothing unexpected happens.

The logical form of (5) is (5a).

(5) Max is winning the race

(5a) $[PROG[BECOME\, winner'(max', race')]]$

In fact, the progressive forms of *all* achievement sentences are represented by a formula of the form $[PROG[BECOME\phi]]$, which receives the following truth conditions.

[2] Dowty himself observes some undesirable consequences of his definition for the operator BECOME, but his criticisms are not relevant for our purposes here.

$[PROG[BECOME\phi]]$ is true in a model M at $\langle I, w\rangle$ just in case there is an interval I' containing I such that I is not a final subinterval of I', and for all $w' \in Inr(\langle I, w\rangle)$, $[BECOME\phi]$ is true at $\langle I', w'\rangle$. This is the case if and only if there is an interval J containing the initial bound of I' such that $\neg\phi$ is true in M at $\langle J, w'\rangle$, and there is an interval K containing the final bound of I' such that ϕ is true in M at $\langle K, w'\rangle$. So the truth of $[PROG[BECOME\phi]]$ requires the temporal structure depicted in figure 4 These truth

Figure 4: *The Temporal Structure for* $[PROG[BECOME\phi]]$

conditions capture the following intuition: if $[PROG[BECOME\phi]]$ is true then *whatever* the current state of affairs is, that state of affairs must lead to the target ϕ in the 'natural course of events'.

According to Dowty, the actual world w is not necessarily a member of the set $Inr(\langle I, w\rangle)$; this captures the intuition that unexpected things can happen in the actual world. Therefore the truth of $[PROG[BECOME\phi]]$ at $\langle I, w\rangle$ does not guarantee the truth of $[BECOME\phi]$ in w. Hence there is no entailment from sentence (6) to (7), which is just as required in order to solve the imperfective paradox.

(6) Max was winning the race

(7) Max won the race

Suppose that $[BECOME\phi]$ is true at an interval I'. Then even though no conditions are placed in the truth conditions of $[BECOME\phi]$ on what goes on during the interval I', it is possible to evaluate the truth value of $[PROG[BECOME\phi]]$ in terms of $[BECOME\phi]$ at all times during I'. In this way, the definition of the progressive in terms of inertia worlds reveals the structure of the interval I' at which $[BECOME\phi]$ is true; i.e. one reveals at what times in I' the process that leads to the target ϕ goes on.

Dowty invokes inertia worlds in the analysis of the progressive to specify when the current state of affairs leads to the target. It is the target happening inertially that is crucial to the analysis of the progressive of achievements. It doesn't matter in evaluating (5) whether Max is ahead or in second place at the time in question.

(5) Max is winning the race

Even though there are endless possible actions corresponding to (5), they all have one thing in common, and that is that they inertially lead to the target state.

Dowty's approach seems fruitful, but one cannot adopt it until one fully understands the notion of *modality* invoked in the definition of the progressive. In Dowty's theory, this amounts to solving the following problem. Can the function Inr be uniquely defined with respect to a given model M, so that the resulting interpretation of the progressive agrees with intuitions? It is inertia specification that gives the analysis of the progressive its "eventual outcome" properties. The question remains as to whether inertia specification is sufficient for describing what is going on at the time of (5) in a way that squares with our intuitions.

5 Inr and Why Figure 1 (The Test Structure) is Inconsistent

In order to explore the nature of Dowty's function Inr we will now ask, relative to Dowty's theory, the question that was posed in section 3. In section 3, I argued that according to intuitions, it is possible for sentence (5) to be true, and then false, and then true, and then Max may go on to win the race. i.e. the situation depicted in figure 1 is a possible state of affairs. The question we ask is: when is sentence (8) true in this scenario?

(8) Max wins the race

Can the period with respect to which (8) is true contain the time at which (5) is false? That is, can we have a semantic interpretation of the progressive and (8) that describes the state of affairs depicted in figure 2 (i.e. in our terminology is The Test Structure consistent)?

This question amounts to the following in Dowty's theory: can $[PROG[BECOME\phi]]$ (where ϕ is the formula $winner'(max', race')$) be true at an index $\langle I, w\rangle$, and then false at $\langle J, w\rangle$ and then true at $\langle K, w\rangle$, where I, J and K are contained in an interval I' and $[BECOME\phi]$ is true at $\langle I', w\rangle$? In other words, is Dowty's version of the temporal structure in figure 2 consistent, as depicted in figure 5?

Figure 5: *Dowty's Version of The Test Structure*

Given that Dowty places no restrictions on what goes on during the interval I' in the truth definition of $[BECOME\phi]$ at I', this seems like a legitimate question to ask. Whether or not The Test Structure is consistent will depend on the semantics of $PROG$, and in particular on how the function Inr is defined. The object of this section is to demonstrate that in order for the function Inr to be well-defined, we must ensure that The Test Structure depicts a state of affairs that is *inconsistent*.

To show this, I will assume the hypothesis that The Test Structure, as depicted in figure 5, *is* consistent, and show that Inr cannot be well-defined under this hypothesis. Suppose that a model M describes the state of affairs depicted in figure 5: i.e. $[PROG[BECOME\phi]]$ is true in M at $\langle I, w\rangle$, false in M at $\langle J, w\rangle$ and true in M at $\langle K, w\rangle$, and $[BECOME\phi]$ is true in M at $\langle I', w\rangle$, where $I < J < K$, and I, J and K are all contained in I'. Then the question we ask is: should w be a member of the inertia worlds at $\langle I, w\rangle$ with respect to M? In exploring this question, we will reveal that the function Inr cannot be well-defined. We first examine the consequences of the assumption that w *is* a member of $Inr(\langle I, w\rangle)$ in the model M.

5.1 Why the Assumption that w is Inertial is Inadequate

Suppose we assume that w is a member of $Inr(\langle I, w\rangle)$ in the model M that describes the state of affairs corresponding to figure 5. Then the resulting interpretation of inertia worlds does not square with intuitions concerning the progressive. It will be shown that this follows from the fact that for *any* model M' where, like the model M, $[PROG[BECOME\phi]]$ is true at $\langle I, w\rangle$ and false at $\langle J, w\rangle$ where $I < J$ and I and J are both contained in an interval I' where Max is running in a race, it is not possible to maintain the supposition that w is inertial at $\langle I, w\rangle$ in M'.

I now argue for this conclusion by considering such a model M'; it will be shown that w cannot be a member of $Inr(\langle I, w\rangle)$ in M'. Consider the following model M': suppose that Max is running in a race at $\langle I', w\rangle$, and suppose that he falls over at $\langle J, w\rangle$, where J is contained in I'. Since Max is lying flat on his face on the track at $\langle J, w\rangle$, according to intuitions, (12), whose logical form is (12a), is true at $\langle J, w\rangle$ with respect to M'.

(12) It is not the case that Max is winning the race

(12a) $\neg[PROG[BECOME winner'(max', race')]]$

Suppose in the model M' that before Max fell over at $\langle J, w\rangle$, he was winning the race. i.e. (5a) is true with respect to M' at $\langle I, w\rangle$, where $I < J$ and I is contained in I'.

(5a) $[PROG[BECOME winner'(max', race')]]$

Then given these assumptions on M', is w inertial at $\langle I, w\rangle$ in M'?

According to intuitions, after the progressive action has been interrupted, *anything* can happen. But the progressive action *is* interrupted in the model M' at $\langle J, w\rangle$ because Max falls over at $\langle J, w\rangle$, and so anything that happens after J in w should be consistent with the truth of (5a) at $\langle I, w\rangle$ where $I < J$. In particular, the truth of (5a) in the model M' at $\langle I, w\rangle$ should be consistent with *Max wins the race* being false in w. But if w is inertial at $\langle I, w\rangle$ in M', then by the definition of $PROG$, the truth of (5a) at $\langle I, w\rangle$ *requires* that Max wins the race in w. This is contrary to intuitions, and therefore one cannot assume that w is inertial at $\langle I, w\rangle$ in the model M', if the definition of the progressive is to agree with its actual use.

This model M' describes a state of affairs that is like the state of affairs depicted in figure 5, in that the formula $[PROG[BECOME\phi]]$ is true at $\langle I, w\rangle$ and then false at $\langle J, w\rangle$, where

I is earlier than J and I and J are both contained in the interval I' where Max is running in the race. Therefore, the argument presented here that w must not be inertial at $\langle I, w\rangle$ in M' supports the claim that w must not be inertial at $\langle I, w\rangle$ in the model M with respect to which the state of affairs in figure 5 is true. What are the consequences of this?

5.2 Circularity

In light of the above, I will now show that the two-place function Inr is not well-defined. Furthermore, if one were to try to modify the function to make it well-defined, then the analysis of the progressive would be reduced to circularity.

In order to show that Inr is not well-defined, we must establish in more depth how to interpret the phrase "an inertia world is one where the state of affairs continues uninterrupted". In the semantic evaluation of a progressive sentence, say (5),

(5) Max is winning the race

do we assume (a) that a world w' is inertial at $\langle I, w\rangle$ with respect to a model M if and only if *all* the states of affairs at $\langle I, w\rangle$ 'continue uninterrupted' in w', or (b) that a world w' is inertial at $\langle I, w\rangle$ with respect to M if and only if the 'winning' event 'continues uninterrupted' in w'? The difference between assumptions (a) and (b) is clear. Assumption (a) entails that *absolutely nothing* can be interrupted in an inertial world, and (b) entails that in the semantic evaluation of (5), only the winning event has to remain uninterrupted. Furthermore, (a) and (b) are the only two possible assumptions, since there are no other plausible ways of picking the inertia worlds if they are to capture a notion of events continuing uninterrupted.

We will now show that assumption (a) is not sustainable, and so inertia worlds must be chosen according to assumption (b). We will demonstrate that assumption (a) is inadequate by means of the following example: suppose that sentences (5) and (13) are both true at $\langle I, w\rangle$ with respect to a model M'.

(13) John is sabotaging the race
(by planting a bomb on the race track that is due to blow up Max before the race is completed).

Let us consider what will happen if the two corresponding events 'continue uninterrupted'. If John succeeds in sabotaging the race, i.e. the bomb goes off and the race is never completed, then Max will not win the race, i.e. Max's winning will be interrupted. On the other hand, if Max's winning the race continues uninterrupted so that he becomes the winner of the race, then John did not succeed in sabotaging the race. So there is no world where both the state of affairs corresponding to (5) and the state of affairs corresponding to (13) continue uninterrupted to the target. Therefore, if assumption (a) is correct, then the set of inertia worlds at $\langle I, w\rangle$ with respect to this model M' will be empty. But this is clearly undesirable, since it follows from this by the definition of $PROG$ that *any* progressive sentence is true at $\langle I, w\rangle$ with respect to M'. Hence assumption (a) is not satisfactory and assumption (b) must hold.

We will now show Inr is not well-defined due to the combination of assumption (b) and the fact that w cannot be inertial at $\langle I, w\rangle$ with respect to M (section 4.1). Suppose that the model M is as described above. That is, M corresponds to the state of affairs in figure 5. Suppose furthermore that in M, $[BECOME\psi]$ is true at $\langle I', w\rangle$ for some state ψ (where ψ is not related to ϕ), and $[PROG[BECOME\psi]]$ is true in w at every interval contained in I'. So the model M corresponds to the temporal structure in figure 6 in w as well as that of figure 5. The state of affairs in figure 6 'continues uninterrupted', since

Figure 6:

the progressive action continues in w from the interval I to the time when the target ψ is true. Therefore according to assumption (b), w must be a member of the inertia worlds at $\langle I, w\rangle$ with respect to the model M in order to obtain the right truth conditions of $[PROG[BECOME\psi]]$. But we concluded in the previous section that w *cannot* be inertial at $\langle I, w\rangle$ if we are to gain the right truth conditions for $[PROG[BECOME\phi]]$. Therefore we have a situation where w is in $Inr(\langle I, w\rangle)$ with respect to M and w is not in $Inr(\langle I, w\rangle)$ with respect to M. Hence the two-place function Inr that takes an interval and a world as its arguments is not well-defined.

How may one modify the function Inr, in order to make it well-defined? If Inr is to be well-defined, then it must be defined relative to the semantic interpretation of *formulae*, as well as intervals and worlds, so that inertia specification in the model M can distinguish the inertial status of w in the semantic evaluations of $[PROG[BECOME\phi]]$ and $[PROG[BECOME\psi]]$. But which formulae are appropriate, and at which indices are their truth values relevant for determining whether w is inertial at $\langle I, w\rangle$ with respect to M?

The semantic values of the formulae ϕ and ψ in the world w cannot be the appropriate arguments to Inr, because they may have identical truth values at all intervals in w with respect to M. This would make the sets of inertia worlds relative to ϕ and ψ identical, and in particular, there would be no means for distinguishing the inertial status of w in the two cases. This, as we have indicated, is contrary to our requirements. A similar argument also demontrates that the truth values of $[BECOME\phi]$ and $[BECOME\psi]$ in the world w are not appropriate input to Inr.

In light of the above, one might choose to define Inr so that the truth values of ϕ in worlds *other than* w play a crucial part in determining whether w is inertial at $\langle I, w\rangle$ in the semantic evaluation of $[PROG[BECOME\phi]]$. In doing this, we would enable the inertial status of w to be different for the two cases we are considering. We could add semantic values of the formulae $\uparrow \phi$ and $\uparrow \psi$, which represent the intension of ϕ and the intension of ψ, as an argument to the function Inr in the truth conditions of $[PROG[BECOME\phi]]$ and $[PROG[BECOME\psi]]$ respectively. In our example, $\uparrow \phi$ and $\uparrow \psi$ denote different propositions. Hence the sets $Inr(\langle I, w\rangle, \uparrow \phi)$ and $Inr(\langle I, w\rangle, \uparrow \psi)$ may be different, which is just as we require.

But although following this course is technically satisfactory, it results in a departure from the intuitions behind the Eventual Outcome Strategy for defining the progressive. The function Inr is supposed to represent the appropriate notion of modality in the Eventual Outcome Strategy, i.e. it must capture the intuitions behind the phrase "if the current state of affairs continues uninterrupted". According to intuitions, whether or not the state of affairs at $\langle I, w \rangle$ continues uninterrupted in w must be determined solely by what happens in w. For example, the fact that Max falls over in some world other than w should not effect our judgement about whether anything unexpected happens to Max's winning in w; one should merely wait and see what happens to Max in w. The assumption we entertain here is that in determining whether w is inertial ("nothing unexpected happens") at $\langle I, w \rangle$ in the semantic evaluation of $[PROG[BECOME\phi]]$, the truth values of ϕ in worlds *other than* w must play a central role. In other words, the inertial status of w at $\langle I, w \rangle$ is not determined by what happens to Max in w alone. This is contrary to our intuitions about the phrase "the state of affairs in w continues uninterrupted", and so if we were to determine the inertial status of w at $\langle I, w \rangle$ with respect to the value of ϕ in worlds other than w, we would be undermining the Eventual Outcome Strategy. A similar argument demonstrates that if $\uparrow [BECOME\phi]$ is added as an argument to Inr, then we would undermine the Eventual Outcome Strategy.

To see what formula must be added as an argument to the function Inr, let's look more closely at our example that shows the current function Inr to be ill-defined. We argued that $[PROG[BECOME\psi]]$ requires w to be inertial at $\langle I, w \rangle$ in the model M on the basis that $[PROG[BECOME\psi]]$ is *true* at $\langle J', w \rangle$ in the model M for every interval J' contained in I'. On the other hand, $[PROG[BECOME\phi]]$ requires w not to be inertial at $\langle I, w \rangle$ in the model M because $[PROG[BECOME\phi]]$ is *false* in the model M at some $\langle J, w \rangle$ where $I < J$ and J is contained in I' (cf. section 4.1). Therefore, in order for Inr to predict that w is inertial at $\langle I, w \rangle$ in M in the semantic evaluation of $[PROG[BECOME\psi]]$ but not in the semantic evaluation of $[PROG[BECOME\phi]]$, Inr must be defined relative to the truth value of the progressive sentence at the intervals contained in I'. i.e. Inr must be a function whose arguments for the semantic evaluation of $[PROG[BECOME\phi]]$ are I, w, and the truth values of $[PROG[BECOME\phi]]$ at times contained in I'.

This leaves us with the following problem in defining Inr. The function Inr is well-defined only if it includes as arguments the truth values of $[PROG[BECOME\phi]]$. But one cannot know the truth values of $[PROG[BECOME\phi]]$ until one has defined Inr. Defining inertia is thus reduced to *circularity*.

We have shown that in the model M that describes the state of affairs depicted in figure 5 (The Test Structure), the two-place function Inr that takes an interval and a world as its arguments is not well-defined. Furthermore, if one were to try and make it well-defined, then the analysis of the progressive would be reduced to circularity. Therefore, the function Inr cannot be defined with respect to the model M. In other words, if The Test Structure is consistent, then one cannot successfully specify Inr.

But specifying Inr is crucial to defining the progressive in terms of eventual outcome in Dowty's theory. Therefore, to preserve the Eventual Outcome Strategy, one must place conditions on the semantics of $PROG$ and $BECOME$ to ensure that The Test Structure is *inconsistent*. In other words, the semantics of $PROG$ and $BECOME$ must ensure that if $[BECOME\phi]$ is true at an interval I, then $[PROG[BECOME\phi]]$ is true at *all intervals* contained in I: i.e. the state of affairs must be that depicted in figure 7 below.

Figure 7: *The Required Relation between $PROG$ and $BECOME$*

6 How to Ensure that The Test Structure is Inconsistent

How may one guarantee that if $[BECOME\phi]$ is true at an interval I, then $[PROG[BECOME\phi]]$ is true at all subintervals of I? I will argue that this temporal structure cannot be satisfactorally derived from Dowty's current semantics for $BECOME$. Furthermore, it cannot be derived by revising the semantics of $BECOME$ without undermining the Eventual Outcome Strategy.

6.1 The Current Semantics for $BECOME$

Suppose one fixes Dowty's semantics for $BECOME$, and suppose that the function Inr is defined so that if $[BECOME\phi]$ is true at the interval I, then $[PROG[BECOME\phi]]$ is true at every interval contained in I (i.e. the state of affairs is that in figure 7). Then although placing conditions on inertia specification to guarantee this temporal structure may be technically viable, it is materially inadequate, given the current truth conditions for $BECOME$. To show this, I will construct a model M'' where the truth of (5) in M'' does not agree with it actual use.

Consider the model M'' where Max is born at $\langle N, w\rangle$, and (8a), which is the representation of (8), is true at $\langle I', w\rangle$ where I' spans twenty years and contains N.

(8) Max wins the race

(8a) $[BECOME winner'(max', race')]$

Such a model is admissible with the current truth conditions for $BECOME$.[3] If inertia

[3] Dowty offers alternative truth conditions for $BECOME$ (call the new operator $BECOME_1$), where $[BECOME_1\phi]$ identifies the *smallest* interval over which the change of state from $\neg\phi$ to ϕ takes place. The definition of $BECOME_1$ requires Dowty to assume that there are truth value gaps; i.e. the truth value of ϕ must be undefined at all intervals properly contained in the interval I at which $[BECOME_1\phi]$ is true. The idea is that ϕ is undefined at exactly those intervals where the process leading to ϕ goes on. But Dowty does not characterise *when* the truth value of a sentence like *Max is the winner of the race* (whose formal representation is $winner'(max', race')$) is undefined. Indeed, if he did then he would undermine the Eventual Outcome Strategy, for he would be characterising the process that leads to Max being the winner of the race *directly* (note that it couldn't be done in terms of inertia worlds because this presupposes the semantics of $BECOME$ is fixed), and he could simply define the progressive sentence as true at exactly those intervals where the truth value of $winner'(max', race')$ is undefined. There would thus be no need for inertia worlds. Since Dowty does not characterise *when* the truth value of $winner'(max', race')$ is undefined, there is still

is specified so that (5a), which is the representation of (5), is true at all times during the interval I', then (5a) is true in M'' at $\langle N, w \rangle$, the time when Max is born.

(5) Max is winning the race

(5a) $[PROG[BECOME winner'(max', race')]]$

This does not accord with the actual use of the progressive. The discrepancy between the truth value of the progressive and its actual use is a direct result of the fact that $BECOME$ does not place conditions in the interpretation of (8) on what goes on *during* I', and so there is no guarantee that the state of affairs during I' is one where the winning process is going on.

The required relationship between $[BECOME\phi]$ and $[PROG[BECOME\phi]]$ cannot be obtained with the current semantics of $BECOME$. The question now is: how should the semantics of $BECOME$ be modified?

6.2 A Change to $BECOME$

How should Dowty's definition of $BECOME$ be revised to ensure that The Test Structure is inconsistent? In other words, how should $BECOME$ be modified so that $[PROG[BECOME\phi]]$ is true throughout any interval I at which $[BECOME\phi]$ is true, in such a way that the truth values assigned by the theory to $[PROG[BECOME\phi]]$ square with the actual use of the progressive? To obtain such a semantics for $BECOME$ the following must hold: if (8a), which represents (8), is true at an interval I, then the semantic definition of $BECOME$ must ensure that the state of affairs during I is one where we would naturally assert (5) as true, e.g. Max is ahead in the race, or he is second but the athlete in first place has just twisted his ankle, etc. In other words, the semantics of $BECOME$ must ensure that all the intervals contained in I are ones where the process that leads to the target is going on, and to achieve this, the semantics of $BECOME$ must *characterise* the process that leads to the target.

The Eventual Outcome Strategy is an attempt to characterise the process that leads to the target in terms of eventual outcome. This is given in the semantics of $[PROG[BECOME\phi]]$, which invokes the semantics of $BECOME$. So one cannot use this Eventual Outcome Strategy to define $BECOME$, or the analysis is reduced to circularity. Instead, the definition of $BECOME$ must characterise the process that leads to the target by placing conditions *directly* on what the process consists of, i.e. it must assert in the case of (8) that the process goes on only if Max is ahead, or second but the athlete in first place has just twisted his ankle, etc.

This goes against the grain of the Eventual Outcome strategy. The aim is to characterise the process purely in terms of *eventual outcome*. Therefore, one undermines the Eventual Outcome Strategy if the semantics for (8) places conditions *directly* on what the process consists of. But we have argued that having such a semantics for (8) is the only way to

the possibility of constructing a model where the interval I', which spans twenty years and contains N, is the shortest interval where the change from $winner'(max', race')$ being false to being true takes place; $winner'(max', race')$ could be undefined throughout I'. Hence there is nothing in the truth conditions of $BECOME_1$ that bars the model M'' from being admissible.

explain that the state of affairs depicted in figure 5 is inconsistent. Hence one cannot modify Dowty's definition of $BECOME$ in order to ensure that figure 5 is inconsistent without undermining the Eventual Outcome Strategy.

I have argued that one cannot explain that figure 5 is inconsistent in Dowty's theory with his current semantics for $BECOME$, and one cannot revise the semantics of $BECOME$ without undermining the Eventual Outcome Strategy. Therefore, figure 5 must be *consistent.*

But this is in conflict with the argument given in section 4, that in order to give a satisfactory specification of Inr, The Test Structure (figure 5) must be an *inconsistent* state of affairs. The semantics of $BECOME$ and the specification of Inr are both essential ingredients to Dowty's formulation of the Eventual Outcome Strategy. For $BECOME$ characterises the culmination of an event, Inr characterises the appropriate modal notion of the current state of affairs continuing uninterrupted, and the Eventual Outcome Strategy defines the progressive in terms of these two things. But Dowty's way of characterising the culmination requires The Test Structure (figure 5) to be consistent and his way of defining the appropriate notion of modality requires The Test Structure to be inconsistent. Therefore, Dowty's formulation of the Eventual Outcome Strategy fails.

Cooper (1985) and Hinrichs (1983) offer alternative formulations of the Eventual Outcome Strategy, this time within the framework of .ul situation semantics. But in (Lascarides 1988), I demonstrated that the argument presented here against Dowty's theory carries over exactly to their formulations of the Eventual Outcome Strategy as well. That is, their ways of characterising the culmination require The Test Structure (figure 2) to be consistent, but their ways of defining the appropriate notion of modality require The Test Structure to be inconsistent. Therefore, although the Eventual Outcome Strategy is intuitively appealing, we have exposed a tension between the two tasks that must be tackled in formulating it.

One is now left with a puzzle. In this part of the paper, I have investigated whether one may canvass in the formal semantic analysis of the progressive the intuition that the common property among the states of affairs that make (5) true is one of eventual outcome, the eventual outcome being the one described by *Max wins the race.*

(5) Max is winning the race

This intuition is not sufficient to yield a satisfactory logical analysis of the progressive however. The puzzle is: how else may the progressive be defined? In the next part of the paper, we will propose an alternative strategy, and show how our new appraoch to aspect may solve the imperfective paradox.

Part II

A New Approach to the Imperfective Paradox

1 Introduction

We will now offer a totally new approach to solve the imperfective paradox, that will make use of a novel semantic interpretation of the classification of aspect. The formal theory offered will rely on two different tools. First, the theory will be expressed in an interval-based temporal logic known as IQ (Richards et al. 1989). Second, we will capture in this theory some of the intuitions that underly Moens and Steedman's model of temporal reference (Moens and Steedman 1988, Moens 1987).

IQ is a temporal logic with at least two innovations. First, like Dowty's theory, IQ adheres to the following principle of *homogeneity*: an atomic sentence is true at an interval I only if it is true at all subintervals of I. However, unlike Dowty's theory, IQ allows atomic formulae to represent non-stative sentences. Second, IQ offers a new technique whereby temporal expressions can have representations that receive their semantic interpretation with respect to *context*.

We will show how homogeneity and context in IQ can be used to characterise the semantics of aspect, where the characterisation is based on Moens' model. This provides a novel way of thinking about the semantics of aspectual phenomena in general, and in particular offers an arena in which to tackle the imperfective paradox anew. We explain the entailment between (14) and (15), and at the same time, explain why no entailment holds between (6) and (7).

(14) Max was running

(15) Max ran

(6) Max was winning the race

(7) Max won the race

Furthermore, we overcome the problems with the Eventual Outcome Strategy. Hence our solution to the imperfective paradox is an improvement on those of Dowty, Cooper and Hinrichs, even though, like Dowty, we offer the solution in an interval-based framework.

2 The Classification of Aspect

As we have discussed, solving the imperfective paradox consists of two tasks. The first is to characterise the semantics of the aspectual classes and so provide distinctions between sentences like (15) and (7), and the second is to provide a definition of the progressive that builds on this characterisation to solve the imperfective paradox. This section is concerned with solving the first task. We use some of the ideas behind Moens' model of aspect to do this.

We will distinguish between three types of sentences; state sentences (e.g. *Max knows the answer*), process sentences (e.g. *Max runs*) and event sentences (e.g. *Max wins the race*, *Max builds a house*). Our state sentences correspond exactly to Vendler's states, and process sentences correspond exactly to Vendler's activities. Events, on the other hand, correspond to Vendler's accomplishments and achievements grouped together in one class. So all our event sentences describe culminations, and some of them are also associated with 'prior' processes that lead to the culmination. The way we capture this in our formalism will shortly be examined in detail.

Moens' taxonomy of aspect contains five categories whereas ours contains only three. Nevertheless, we will exploit some of the ideas that lie behind his classification of aspect. One of these is the way in which an event can be analysed into stages that are identified deictically, i.e. by extra-linguistic context. For example, the process that leads to the culmination described by sentence (16), i.e. that the house gets completed, will be identified deictically.

(16) Max build a house

In the context where Max is spending money on building materials with the intention of building a house, *Max is building a house* is true and the process it refers to is Max spending money on building materials. But in the context where Max is spending money on building materials without the intention of building a house, *Max is building a house* is false, and the process it describes is *not* Max spending money on building materials. It is this intuition that we aim to capture in our semantics.

Since our theory will be expressed in IQ a few remarks about this semantic framework are in order.

3 An Informal Introduction to IQ

IQ (standing for Indexical Quantification) is an interval-based framework originally designed to provide a formal semantic treatment of tense and temporal quantification in English (Richards et al. 1989). Similarly to Dowty's theory, propositions are functions from world-interval pairs to truth values; this is why IQ is viewed as an interval-based framework.

IQ offers a new technique for representing deictic expressions (i.e. those expressions that are not fully interpretable independently of extra-linguistic context). This is achieved by invoking in the object language of IQ a set of referring expressions known as *parameters*, which are used to represent deictic terms like *this* and *that*.

A possibly partial function g_c, which is known as the indexical function and which forms part of the model for IQ, assigns denotations to the parameters. For historical reasons, the subscript c on g_c stands for extra-linguistic *context*, but don't be confused: the function g_c is *fixed* for any given model and so will not change as the natural language discourse being considered progresses.

Instead of g_c changing as the context of utterance changes, the parameters in the representations of the utterance will change, thus enabling the same sentence to refer to different things in different contexts of utterance with respect to the same model. This technique of using different terms for representing the same natural language expression in different utterances is used by Montague in his analysis of pronouns. Just as his theory makes no claims for representing the mechanism we use in resolving pronouns, our theory will not represent the mechanism we use in resolving deictic expressions. Nevertheless, because the parameter used for representing a demonstrative like *that* will be different for different utterances of *that*, one can think of parameters as deictic in nature, for we will achieve different references for *that* in different contexts. Any expression in the object language will 'inherit' the deictic nature of the parameters it invokes, as its semantics will depend on the denotation of these parameters, which are determined by the indexical function g_c. We will use parameters to capture in our semantics the idea that sentences may describe the stages of a particular event where these stages are identified by extra-linguistic context.

3.1 The Syntax and Semantics

The language of IQ (henceforward referred to as Liq) is an extension of the ordinary predicate calculus, which contains the usual constants, variables, n-place predicates, truth functional connectives and quantifiers. The constants and variables are *sorted* into four domains in the extended version of IQ that we are going to use here; they range over individuals, possible worlds, intervals of time and propositions.[4] I stress that this is an extended version of the framework of IQ, where the language has referring expressions that denote propositions. The standard framework of IQ does not invoke any such referring expressions.

To achieve a deictic analysis of tense, Liq has a set of referring expressions over and above constants and variables. As I have already mentioned, these are *parameters*, and the indexical function g_c assigns parameters their denotations. In fact, parameters are rigid designators. The parameters are 'sorted' like the constants and variables, and in the extended version of IQ that we are discussing here they range over the four domains of individuals, worlds, intervals and propositions. Parameters occur in the syntax of Liq on deictic sentential operators such as tense. They appear as subscripts on the operators: for example the past tensed version of an untensed sentence A (such as $win(max, race)$) is represented as $PAST_{(v,t)}(A)$, where v is a parameter which ranges over the domain of possible worlds, and t is a parameter which ranges over the domain of intervals of time. $PAST_{(v,t)}(A)$ is true if the following holds:

- $PAST_{(v,t)}(A)$ is true at the world-time index (w, i) if and only if $g_c(v) = w$, $g_c(t) = i$ and there exists an interval j earlier than i such that A is true at (w, j).

In the above definition the function g_c assigns the parameters v and t the 'place' (i.e. possible world) and time of speech. Thus Richards' analysis of tense is Russellian in that it refers essentially to speech time.[5] For a full discussion of the novel properties of this definition of tense, see (Richards et al. 1989). In our theory, parameters will not only play a central role in tense, but also in aspect.

A *model* for Liq is a septuple $\langle f, W, I, F, \ll, g_c, f \rangle$ where the four non-empty sets D, W, I, and F correspond respectively to the domains of individuals, possible worlds, intervals of

[4]An extended version of IQ, that includes referring expressions ranging over propositions, is used to account for *temporal connection* (Richards et al. 1989).

[5]IQ's tenses are deictic in a limited way; they don't invoke definite reference to (say) past time. cf. Partee (1973) for an alternative view of the deictic nature of tense.

time and propositions; $\ll$ is a partial ordering relation on the domain I of intervals; g_c is the function that assigns parameters their denotations; and f is the interpretation function which assigns the non-logical constants of Liq their intensions.

The interpretation function f is designed so as to maintain a certain degree of *homogeneity.* That is, the truth clauses for the expressions of Liq are such that the definition of truth will yield the following homogeneity property for atomic formulae of Liq (which I will subsequently define) and their boolean combinations:

- An atomic formula (e.g. $win(max, race)$, $run(max)$) or a boolean combination of atomic formulae is true at an index (w, i) only if for all subintervals j of i it is true at (w, j).

The above homogeneity principle is fundamental to the framework IQ, and the way it is used sets IQ apart from other interval-based frameworks, such as (Dowty 1979). Dowty represents the sentence *Max win the race* so that it may be true at an interval i and false at an interval j contained in i. This is not the case for IQ, for *Max win the race* is represented by an atomic formula (i.e. $win(max, race)$[6]) and so is subject to the above homogeneity restriction.

It must be stressed, however, that the homogeneity restriction will not apply to *all* the sentences of the language, but only the boolean combinations of the atomic sentences.

So to summarise, there are basically two leading ideas in IQ. First, there are certain temporal expressions, such as tense, whose semantic interpretations are essentially about the context of utterance. Second, the framework of IQ is designed so as to maintain the above *homogeneity* restriction. Now that the general motivation for Liq is in place, I will give the formal definitions of the syntax and semantics of Liq.

4.1 The Syntax

The basic expressions of Liq are defined below:

(i) Four countably infinite sets of *variables*: V_D, V_W, V_I, and V_F.
(ii) Four (possibly empty) sets of name *constants*: C_D, C_W, C_I, and C_F.
(iii) Four (possibly empty) sets of *parameters*: P_D, P_W, P_I, and P_F.
(iv) For $n \geq 0$ a countably infinite set P^n of n-place *predicate constants.*
(v) *Quantifiers*: $\exists$, $\forall$.
We read $\exists$ and $\forall$ as *some* and *all* respectively.
(vi) The set of D-terms is $V_D \cup C_D \cup P_D$, the set of W-terms is $V_W \cup C_W \cup P_W$, the set of I-terms is $V_I \cup C_I \cup P_I$, and the set of F-terms is $V_F \cup C_F \cup P_F$.
(vii) *Tense* operators: $PRES_{(v,t)}$, $PAST_{(v,t)}$, $FUT_{(v,t)}$, where $v \in P_w$ and $t \in P_I$.

The well formed formulas (wffs) of Liq can now be defined inductively in the familiar way.

(i) Where R_n is an n-place predicate constant and $d_1, \ldots, d_n$ are D-terms, $R_n(d_1, \ldots, d_n)$ is an atomic wff.
(ii) Where A is a wff and x belongs to V_D, $\exists x A$ and $\forall x A$ are wffs.
(iii) If A is a wff and Π is a tense operator, ΠA is a wff.

[6] We will view *race* as a term in order to simplify the analysis for our purposes here.

4.2 The Semantics

Although IQ is an interval-based system, points play an essential role. In effect, intervals are connected sets over points of time, and their ordering is determined by the partial ordering of the points of time in the intuitive way (an interval i is earlier than an interval j iff all the points in i are earlier than all the points in j).

An IQ-structure M is defined as follows: M is a septuple $\langle D, W, I, F, \ll, g_c, f\rangle$ such that

(a) D, W and I are disjoint nonempty sets to be understood respectively as the set of possible objects, possible worlds, and intervals of time. The non-empty set F is understood as the set of propositions (built from the sets W and I). It consists of all functions from $W \times I$ to the truth values $\{0, 1, u\}$ (u is to be glossed as *undefined*).

(b) $\ll$ is the partial ordering of I induced by the ordering on the set of points of time.

(c) g_c is a function (the 'indexical' function) from the parameters of Liq to corresponding denotations.

(d) f is a function which assigns to the constants of Liq the suitable (possibly partial) intensions from $W \times I$.

The interpretation function f is subject to the following *homogeneity* restrictions (these will yield the homogeneity principle described in the previous section):

(i) For every name constant b and predicate r_n, $f(b)(w,i)$ and $f(r_n)(w,i)$ are defined for all (w,i) in $W \times I$, where i is a singleton.

(ii) For all name constants b, $f(b)(w,i) = f(b)(w,j)$ for all j included in i (all subintervals of i).

(iii) for any predicate constant r_n, $f(r_n)(w,j)$ is included in $f(r_n)(w,i)$ for all subintervals i of j.

Because of the homogeneity restrictions on f, intensions will typically be partial. However, the appropriate valuation space for an IQ-structure is one with three truth-values: 1 (*true*), 0 (*false*) and u (*undefined*). A formula will have the value u whenever any of its non-logical constants are undefined. It must be stressed that u is a third truth value rather than a truth value gap. The *truth definition* for Liq proceeds in terms of the notion of an IQ-*interpretation* based on an IQ-structure M.

- An IQ-interpretation is a pair $\langle M, g\rangle$ such that M is an IQ-structure and g is a function which assigns values to the variables of Liq.

Given an IQ-interpretation, the denotation of a well-formed expression β is defined recursively in the familiar way. We let $[\![\beta]\!]^{\langle M,g\rangle}(w,i)$ be the denotation of β relative to the IQ-interpretation $\langle M, g\rangle$ with respect to the pair $(w,i) \in W \times I$. $[\![\beta]\!]^{\langle M,g\rangle}$ is defined recursively in the following way.

(a) Where β is a variable, $[\![\beta]\!]^{\langle M,g\rangle}(w,i) = g(\beta)$.
(b) Where β is either a name constant or a predicate constant, $[\![\beta]\!]^{\langle M,g\rangle}(w,i) = f(Gb)(w,i)$.
(c) Where β is a parameter, $[\![\beta]\!]^{\langle M,g\rangle}(w,i) = g_c(\beta)$.
(d) Where β is an atomic wff $p^n(d_1,\ldots,d_n)$, $[\![\beta]\!]^{\langle M,g\rangle}(w,i) =$
1 if $\langle [\![d_1]\!]^{\langle M,g\rangle}(w,i),..,[\![d_n]\!]^{\langle M,g\rangle}(w,i)\rangle$ belongs to $[\![p^n]\!]^{\langle M,g\rangle}(w,i)$,
0 if $\langle [\![d_1]\!]^{\langle M,g\rangle}(w,i),..,[\![d_n]\!]^{\langle M,g\rangle}(w,i)\rangle$ does not belong to $[\![p^n]\!]^{\langle M,g\rangle}(w,i)$,
u if $[\![d_i]\!]^{\langle M,g\rangle}(w,i)$ is undefined for any i where $1 \leq i \leq n$ or $[\![p^n]\!]^{\langle M,g\rangle}(w,i)$ is undefined.
(f) Where β is a wff $\forall x A$ with the individual variable x, $[\![\beta]\!]^{\langle M,g\rangle}(w,i)$ is
1 if $[\![A]\!]^{\langle M,g(x,e)\rangle}(w,i) = 1$ for some e belonging to D[7],
0 if $[\![A]\!]^{\langle M,g(x,e)\rangle}(w,i) = 0$ for all e belonging to D,
u otherwise.
(g) Where β is a wff $\forall x A$ with the individual variable x, $[\![\beta]\!]^{\langle M,g\rangle}(w,i)$ is
1 if $[\![A]\!]^{\langle M,g(x,e)\rangle}(w,i) = 1$ for all e belonging to D,
0 if $[\![A]\!]^{\langle M,g(x,e)\rangle}(w,i) = 0$ for some e belonging to D,
u otherwise.
(h) Where β is a wff $PRES_{(v,t)}(A)$ with $v \in P_w$ and $t \in P_I$, $[\![\beta]\!]^{\langle M,g\rangle}(w,i)$ is
1 if $[\![v]\!]^{\langle M,g\rangle} = w$ and $[\![t]\!]^{\langle M,g\rangle} = i$ and $[\![A]\!]^{\langle M,g\rangle}(w,i) = 1$,
0 if $[\![v]\!]^{\langle M,g\rangle}$ and $[\![t]\!]^{\langle M,g\rangle}$ are defined but $[\![v]\!]^{\langle M,g\rangle} \neq w$ or $[\![t]\!]^{\langle M,g\rangle} \neq i$ or $[\![A]\!]^{\langle M,g\rangle}(w,i) = 0$,
u otherwise.
Where β is a wff $PAST_{(v,t)}(A)$ with $v \in P_w$ and $t \in P_I$, $[\![\beta]\!]^{\langle M,g\rangle}(w,i)$ is
1 if $[\![v]\!]^{\langle M,g\rangle} = w$ and $[\![t]\!]^{\langle M,g\rangle} = i$ and $[\![A]\!]^{\langle M,g\rangle}(w,j) = 1$ for some $j \ll i$
0 if $[\![v]\!]^{\langle M,g\rangle}$ and $[\![t]\!]^{\langle M,g\rangle}$ are defined but $[\![v]\!]^{\langle M,g\rangle} \neq w$ or $[\![t]\!]^{\langle M,g\rangle} \neq i$ or $[\![A]\!]^{\langle M,g\rangle}(w,i) = 0$ for all $j \ll i$
u otherwise.
Where β is a wff $FUT_{(v,t)}(A)$ with $v \in P_w$ and $t \in P_I$, $[\![\beta]\!]^{\langle M,g\rangle}(w,i)$ is
1 if $[\![v]\!]^{\langle M,g\rangle} = w$ and $[\![t]\!]^{\langle M,g\rangle} = i$ and $[\![A]\!]^{\langle M,g\rangle}(w,k) = 1$ for some k such that $i \ll k$,
0 if $[\![v]\!]^{\langle M,g\rangle}$ and $[\![t]\!]^{\langle M,g\rangle}$ are defined but $[\![v]\!]^{\langle M,g\rangle} \neq w$ or $[\![t]\!]^{\langle M,g\rangle} \neq i$ or $[\![A]\!]^{\langle M,g\rangle}(w,i) = 0$ for all k such that $i \ll k$,
u otherwise.

The above truth definition (d) for atomic wff together with the homogeneity restrictions (i), (ii) and (iii) on f yield the homogeneity principle in (17).

(17) An atmoic sentence or a boolean combination of atomic sentences will be true at an index (w,i) only if for all subintervals j of i, it is true at (w,j).

Now that the syntax and semantics of the language of IQ are in place, I will explore how one might implement the suggestions outlined earlier: to formulate the taxonomy of aspect in the framework IQ.

[7] g(x,e) is the same as g save that g(x,e)(x) = e

4 Formulating the Taxonomy of Aspect in IQ

If the distinctions between the three aspectual classes of states, processes and events are to be thought of as *semantic* distinctions, then the task ahead is to provide a suitable model structure that captures this. The set F of propositions, which corresponds to the set of all functions from $W \times I$ to $\{0, 1, u\}$, must be divided into at least three classes corresponding to the three aspectual categories: F must consist of a set S of state propositions, a set Pr of process propositions and a set E of event propositions. So a state sentence, such as *Max know the answer*, will be represented in IQ as the atomic formula $know(max, answer)$, and this formula will denote a state proposition; i.e. a member of the set S. The process sentence *Max run* will be represented by the atomic formula $run(max)$, which will denote a member of Pr. The event sentences *Max win a race* and *Max build a house* will be represented respectively by the atomic formulae $win(max, race)$ and $build(max, house)$, and they will both denote members of E.

Our task now is to provide a way of distinguishing the members of S, Pr and E. How may this be done?

First, let us consider what restrictions we require on the set E of event propositions. I will claim that because of the *homogeneity principle*, any proposition from E must return the value true only at minimal intervals, (these are the singleton sets in IQ). For suppose that an atomic untensed sentence A denoting an event proposition is true at an extended interval i, however small. Then by homogeneity A is true at every subinterval of i. One is now committed to one of two undesirable consequences. The first alternative is that the structural representation of A is not related to the 'goal' or 'conclusion' of the event it denotes. The second alternative is that A has a 'goal' or 'conclusion' associated with it, but homogeneity establishes that this conclusion occurs at every interval contained in i (since A is true at every interval contained in i). Hence a homogeneous interpretation of events is satisfactory only if they are true only at *minimal* intervals. Under this restriction, the structural representation of A can entail a 'goal' or 'conclusion', which will occur at the minimal interval at which A is true.

The analysis of event propositions that we have been forced into by homogeneity may at first seem puzzling. According to intuitions, some events such as *Max build a house* do seem to extend in time, and yet we represent events as punctual entities. The puzzle is: How are we to formulate in this framework the intuition that some events have 'preparatory' processes that lead to the culmination? This puzzle will shortly be addressed in full. The technique whereby expressions in IQ can achieve semantic interpretation with respect to extra-linguistic context will play a central role in answering it.

The 'punctual' property of event propositions is captured in the following analysis of F. The set F is partitioned into four classes; Pr (process propositions), S (state propositions), E (event propositions), and Φ (the remaining functions in F).

The conditions placed on the members from these classes are as follows:

- *Condition on E*
  $e \in E$ if and only if for all $(w, i) \in W \times I$ such that $e(w, i) = 1$, i is a *minimal interval.*

If $e \in E$, then the function e returns the value true only at minimal intervals. The fact that the members of E have this 'minimal interval' property reflects the idea that the culmination of an event is punctual (for it happens at the minimal interval at which the event is true).

In classifying the set Pr of process propositions, we capture Moens' idea that processes essentially extend in time and have definite endpoints (but *not* culminations). The propositions in Pr satisfy the following:

- *Condition on* Pr
  $pr \in Pr$ if and only if for all indices $(w, i) \in W \times I$, if $pr(w, i) = 1$ and if for all intervals j such that i is contained in j $pr(w, j) = 0$, then i is a closed non-minimal interval.

By the above condition, if $pr \in Pr$, then it has what I call a *closed interval* structure. That is, the proposition pr may be true on an open interval, but any such interval is surrounded by a non-minimal closed interval at which pr is true. Similarly, any minimal interval at which pr is true is surrounded by a non-minimal closed interval at which pr is true. Essentially, the maximal (connected) intervals at which a process proposition returns the value true are always non-minmal and closed. The fact that these are non-minimal reflects the intuition that processes happen over an extended period, and the fact that they are closed reflects the intuition that they have definite endpoints (but *not* culminations).

The classification of the set S of state propositions captures the idea that states essentially extend in time but do not have definite endpoints. The propositions in S must satisfy the following condition:

- *Condition on* S
  $s \in S$ if and only if for all $(w, i) \in W \times I$, if $s(w, i) = 1$ and if for all intervals j such that i is contained in j $s(w, j) = 0$, then i is open.

So if $s \in S$, then it has what I call an *open interval* structure. That is, the function s may be true on a closed interval, but any such interval is surrounded by an open interval at which s is true. So essentially the maximal (connected) intervals at which a state proposition returns the value true are always open. The fact that they are open reflects the intuition that states don't have definite endpoints.

The functions that are in the set Φ satisfy the following condition:

- *Condition on* Φ
  $\phi \in \Phi$ if and only if none of the conditions on E, Pr, or S hold.

So the largest intervals at which a function $\phi \in \Phi$ returns the value true are a mixture of open, closed and minimal. The set of functions Φ does not correspond to any of the aspectual categories, but is included as a subclass of F since F contains *all* functions from $W \times I$ to $\{0, 1, u\}$.

5 The Preparatory Process of an Event

As we have already mentioned, we intend to represent the event sentence *Max build a house* with the atomic formula $build(max, house)$, and this formula will denote an event proposition. So $build(max, house)$ will be true at an interval i only if i is minimal.

Given this analysis of the event sentence *Max build a house*, how can we provide a semantic interpretation of the preparatory process of building a house, that leads to the culmination of the house being completed? The challenge is to provide a *temporal relation* between this process and the event $build(max, house)$. For Dowty, the preparatory process that leads to the culmination of an event occurs *during* the interval at which the event itself occurs. Clearly, we need to provide a different temporal relation to this, for our events are true only at minimal intervals, and so the process cannot occur at an interval contained in the minimal intervals.

We propose to define the process that leads to the culmination of an event in terms of the event itself: If A is an event sentence, then $PR(A)$ is a sentence that represents the process that leads to the culmination of A, where PR is a sentential operator. Our task now is to define the semantics of this sentential operator PR. In so doing, we must stipulate the temporal relation that holds between A and $PR(A)$.

In characterising this temporal relation, the intuition we will trade on is that whenever the event (i.e. culmination) occurs, the preparatory process that leads to the culmination must have been going on just before. This *temporal precedence* relation between a preparatory process and culmination is formulated in (R) below:

(R) If the event sentence A is true at (w, i), then there is some interval j such that i is the final bound of j and $PR(A)$ is true at (w, j)[8]

Note that (R) expresses a *necessary* relation between A and $PR(A)$, since it must hold for every world-time index.

But simply stating (R) does not supply a full semantic analysis of the sentence $PR(A)$. The relation (R) will not uniquely specify the proposition pr that the sentence $PR(A)$ denotes. So what is the proposition denoted by $PR(A)$?

Our proposal is that the process proposition (18) refers to, for example, is not uniquely specified independently of its context of utterance.

(18) $PR(build(max, house))$

Extra-linguistic context will determine the process that (18) refers to, but the semantics for (18) will be such that the possible choice for this process is subject to the restriction that it must satisfy the necessary relation (R) to $build(max, house)$. So, as we mentioned before, in the context where Max is spending money on building materials with the intention of building a house, (18) will be true, and the process it refers to will be Max spending money on building materials. But in the context where Max is spending money on building materials without the intention of buiding a house, (18) will be false, and the process it refers to will not be Max spending money on building materials.

To formulate this idea in our theory, we will *replace* the sentential operator PR with a *complex* sentential operator PR_p, where p is a referring expression that will refer to a process proposition which is identified by extra-linguistic context. So the preparatory process of

[8]The minimal interval i is the final bound of j if and only if $i = \{t\}$ and t is the supremum of the set of points that make up j.

building a house is now represented with (19),

(19) $PR_p(build(max, house))$

and the semantics of $PR_p(A)$ will define a relation between the event proposition denoted by A and the process proposition denoted by p, whose value is determined by extra-linguistic context.

But how can the logical analysis of $PR_p(A)$ be defined so as to refer to a proposition denoted by p whose value is determined by extra-linguistic context?

The preceding discussion indicates that the relation between the sentence $PR_p(A)$ and context is a matter of logical form. IQ provides us with just the technique we need to capture this idea. We make the referring expression p in the sentence $PR_p(A)$ a *parameter* that denotes a proposition. It will thus achieve denotation with respect to extra-linguistic context via the indexical function g_c that is part of the model. In the truth conditions of $PR_p(A)$, the parameter p is to be thought of as describing the preparatory process of A whose value is determined by context. So, in the building a house example that we have been considering, $g_c(p)$ could be $[\![spend(max, money, building - materials)]\!]$, where the formula $spend(max, money, building - materials)$ represents the process of Max spending money on building materials.

5.1 The Truth Conditions of $PR_p(A)$

We have already mentioned two conditions that must hold for $PR_p(A)$ to be true. First, p must denote a process proposition and A must denote an event proposition. This ensures that the semantics of $PR_p(A)$ relates a process to an event. Second, there must be a temporal precedence relation between the preparatory process of A and A itself. Since the parameter p is to be thought of as describing the preparatory process of A, whose value is identified by context, this entails that the truth of $PR_p(A)$ enforces the condition that whenever A is true, the proposition denoted by p must have been true just before. So although the denotation of p is chosen according to extra-linguistic *context*, the possible choices will be *semantically* restricted by this temporal precedence relation with A.

The above requirements on the semantics of Pr_p are captured in its following truth conditions:

$PR_p(A)$ is true with respect to $\langle M, g\rangle$ at (w, i) if

(a) the proposition denoted by A (which we refer to as $[\![A]\!]^{\langle M,g\rangle}$) is a member of E, and $g_c(p)$ is a member of Pr, and
(b) for all indices $(w', i') \in W \times I$, if $[\![A]\!]^{\langle M,g\rangle}(w', i') = 1$ then there is an interval j' whose final bound is i' and $g_c(p)(w', j') = 1$, and
(c) $g_c(p)(w, i) = 1$;

it is false if either conditions (a), (b) or (c) do not hold;
and otherwise it is undefined.

Let us discuss the semantic roles of the conditions (a), (b) and (c) in the above definition.

Condition (a) requires A to denote an event proposition and p to denote a process proposition. Hence the operator PR_p operates on an *event* sentence, and it also invokes reference to a *process* proposition whose value is determined by context, which is as required.

Condition (b) states that the process proposition $g_c(p)$ and the event proposition denoted by A stand in a necessary temporal precedence relation; whenever A occurs, p occurs just before. The result of condition (b) is effectively to semantically restrict our possible choices for $g_c(p)$. It captures the intuition that the truth of A must be the *result* of the process $g_c(p)$ that was going on just beforehand. Condition (b) also ensures that $PR_p(A)$ and A will stand in the temporal precedence relation (R) mentioned earlier.

According to condition (c), $PR_p(A)$ is true at (w, i) only if $g_c(p)(w, i) = 1$. It is important to note that $PR_p(A)$ is defined in terms of, among other things, the sentence A, but the truth of $PR_p(A)$ at (w, i) does not entail the truth of A at any time. This reflects the intuition that the preparatory process of A may go on without the culmination ever being reached. Our ability to formulate this intuition in IQ will prove important when it comes to solving the imperfective paradox.

Furthermore, by conditions (a), (b) and (c), we can show that the sentence $PR_p(A)$ denotes a proposition from Pr. For suppose that $PR_p(A)$ is true at the index (w, i). Then by condition (a) $g_c(p) \in Pr$ and by condition (c) $g_c(p)$ is true at (w, i). So by the properties of propositions in Pr, either i is a non-minimal closed interval, or i is contained in a non-minimal closed interval j such that $g_c(p)$ is true at (w, j). Suppose i is contained in a non-minimal closed interval j such that $g_c(p)$ is true at (w, j). Then given that $PR_p(A)$ is true at (w, i), conditions (a) and (b) are satisfied for the evaluation of $PR_p(A)$ at (w, j) (because these conditions are independent of the index of evaluation). So since $g_c(p)$ is true at (w, j), then by condition (c) so is $PR_p(A)$. Hence if $PR_p(A)$ is true at (w, i) then either i is a non-minimal closed interval or i is contained in a non-minimal closed interval j such that $PR_p(A)$ is true at (w, j). Hence the proposition denoted by $PR_p(A)$ satisfies the condition on the set Pr, and so it must be a process. This is just as required: we want $PR_p(A)$ to denote a process proposition since it represents the preparatory process of the event A.

Also note that as long as $PR_p(A)$ is possibly true with respect to a model M, then it satisfies the temporal precedence relation (R) with A. For if $PR_p(A)$ is true at some index, then by condition (a) $g_c(p)$ is defined (remember that g_c is partial) and by condition (b), whenever A is true, $g_c(p)$ is true just before. Therefore by condition (c), whenever A is true $PR_p(A)$ is true just before. In essence, this captures in our semantics the idea that the event is the result of a preparatory process which is chosen in a suitable way from context.

Finally, note that although the formula $PR_p(A)$ and the referring expression p may denote the same proposition, the definition of $PR_p(A)$ is not circular even though it is given in terms of p. This is because $g_c(p)$ is not defined *in terms* of $PR_p(A)$. g_c is simply a one-place function that assigns the term p a proposition as its denotation. Context will determine whether the proposition denoted by p in $PR_p(build(max, house))$ will be true when the plans for the house are being determined, or whether p is true only when the action of building is going on, for example.

Let us consider sentence (3).

(3) Max was building a house

The analysis of (3) will have embedded in it the sentence (19) (the full analysis of (3) that incorporates the representation of the progressive will be given shortly).

(19) $PR_p(build(max, house))$

The value of p, i.e. $g_c(p)$, is some proposition that is picked out deictically; as we have mentioned it could be the proposition denoted by $[\![spend(max, money, building - materials)]\!]$.[9] The choice of $g_c(p)$ determines which process is said to be in progress when we utter (3). Note that sentence (19) is true at (w, i) only if $g_c(p)$ is true at (w, i), but it does not assert that $build(max, house)$ is ever true.

6 Our Approach Compared with Previous Interval-Based Approaches

We have now completed the first task connected with the imperfective paradox: we have formulated the classification of aspect in an interval-based framework, and in so doing have provided semantic distinctions between process sentences like *Max run* and event sentences like *Max build a house.* Let us see how our analysis of the classification of aspect compares with previous interval-based accounts.

Dowty's interval based formulation of the classification of aspect features a heterogeneous semantics for *accomplishments* such as *Max build a house* where this sentence may be true at an interval i and false at a subinterval of i.

Our interpretation of the classification of aspect takes on a wholly different approach from Dowty's. We do not give a heterogeneous analysis of the untensed sentence *Max build a house.* Indeed, such truth conditions for *Max build a house* would not even be expressible in the framework IQ because of the homogeneity principle (17), which entails that if $build(max, house)$ is true at (w, i), then it is true at (w, j) for all subintervals j of i.

(17) An atomic sentence or a boolean combination of atomic sentences is true at the index (w, i) only if for all subintervals j of i, it is true at (w, j).

Thus one important original feature of our theory is that it is the first formulation of the classification of aspect where the various aspectual classes are assigned a homogeneous analysis. And yet even though our analysis of aspect is homogeneous, we can capture all the important intuitions that are captured in Dowty's heterogeneous analysis; for example the intuition that events can have preparatory processes.

Dowty characterises the process of Max building a house purely in terms of the eventual outcome of the current state of affairs, but we use something else. Instead of the semantics of $PR_p(build(max, house))$ being in terms of the eventual outcome, the *extra-linguistic context* of utterance plays a crucial part, for its semantics is dependent on the value of $g_c(p)$. Hence our strategy is distinct from the Eventual Outcome Strategy.

[9] How g_c assigns this reference to p is not a matter we shall discuss here.

It is shown in (Lascarides 1988) that in using our strategy of identifying parts of an event via extra-linguistic context, one can account for the fact that sentence (20) is acceptable in certain contexts but not in others.

(20) Max ran in four minutes (this morning)

(20) is acceptable in the context where Max runs a fixed distance every morning. For example, in the context where Max runs a mile every morning, the culmination is Max reaching the distance of one mile, and (20) means it took four minutes for Max to run a mile. In the context where Max runs two miles every morning, the culmination in the semantics of the *event Max run* is identified as Max reaching the distance of two miles, and (20) means it took four minutes for Max to run two miles. In (Lascarides 1988) we show how to characterise the semantics of the *event* sense of *Max run* as it appears in (20), where the culmination is identified by context. Our formal theory is able to account for this by invoking a parameter in the representation of the event *Max run* which will identify the appropriate culmination (if there is one) given the context. Because deixis does not play a central role in Dowty's theory on aspect, he is unable to account for the fact that the acceptability of (20) is dependent on the context in which it was uttered.

So to conclude, I have offered a formal interpretation of the taxonomy of aspect in the framework IQ. The theory offered a new approach to formalising the taxonomy of aspect because it contained essentially two original features; the aspectual classes are assigned a *homogeneous* interval-based analysis, and context plays a central role in describing their semantics. Thus this formulation of the taxonomy of aspect provides an arena in which to tackle the imperfective paradox anew. Can our theory yield a solution to the imperfective paradox, in a way that overcomes the problems encountered in previous attempts?

7 A Solution to the Imperfective Paradox

Our objective now is to deal with the second task connected with the imperfective paradox; to build on the classification of aspect we have proposed by defining the semantics of the progressive that solves the imperfective paradox.

A satisfactory solution to the imperfective paradox must explain the entailment from sentence (14) to (15), and at the same time explain why there is no entailment from (6) to (7).

(14) Max was running

(15) Max ran

(6) Max was winning the race

(7) Max won the race

One would also like an explanation of the entailments from (15) to (14), and (7) to (6). This section is concerned with providing an analysis of the progressive that accounts for these intuitions.

Moens claims that the progressive requires a process as input, and it outputs a state which describes the process as being in progress. To reflect this idea in our semantics, we will represent the progressive as an operator $PROG$, that will operate on the process sentence A, so that $PROG(A)$ denotes a state proposition which describes the process A as being in progress. That is, $PROG(A)$ will assert that the process A began at some earlier time and has not yet stopped. The truth definition of $PROG$ is given below:

- $PROG(A)$ is true with respect to $\langle M, g\rangle$ at (w, i) if and only if $[\![A]\!]^{\langle M,g\rangle} \in Pr$ and there exists a closed interval j such that i is a proper subinterval of j and A is true at (w, j); it is false at (w, i) if either $[\![A]\!]^{\langle M,g\rangle}$ is not a member of Pr, or there is no closed interval j such that i is a proper subinterval of j and A is true at (w, j); and otherwise it is undefined

The sentence $PROG(A)$ is false where A does not denote a process proposition. Furthermore, the sentence $PROG(A)$ must denote a state proposition, since the largest connected intervals at which $PROG(A)$ is true are the *open* interiors of the largest connected intervals at which A is true, and so $PROG(A)$ satisfies the condition on the members of S that we have stipulated. Since $PROG(A)$ is true at the open *interior* of the interval where A is true, our definition of $PROG(A)$ reflects the idea that it is true if the process A started at some earlier time and has not yet stopped.

7.1 The Entailments from the Progressive to the Non-Progressive

At first glance, the operator $PROG$ does not seem to offer anything interesting towards a solution to the imperfective paradox. However, the combination of the operators $PROG$ and PR_p provide us with the desired analysis of sentence (6); (6) does not entail (7).

(6) Max was winning the race

(7) Max won the race

The formula (21) is not a possible representation of (6) because the formula $win(max, race)$ denotes a proposition from E and *not* a proposition from Pr, and so by the definition of $PROG$, (21) is always false.

(21) $PAST_{(v,t)}[PROG(win(max, race))]$

In fact, the only possible representation of (6) in our formalism is (6a).

(6a) $PAST_{(v,t)}[PROG[PR_p(win(max, race))]$

I will now show that our theory blocks the entailment from (6) to (7). I will do this by constructing a model M such that (6a) is true in M at (w, i) and (7a), which is the logical form of (7), is false.

(7a) $PAST_{(v,t)}(win(max, race))$

Suppose that sentence (6a) is true in a model M at an index (w, i). This is the case if and only if $g_c(v) = w$ and $g_c(t) = i$, and there exists an interval $j \ll i$ such that (6a′) is true at (w, j).

(6a′) $PROG[PR_p(win(max, race))]$

This is the case if and only if (6a″) denotes a process proposition, and there exists a closed interval k such that j is a proper subinterval of k and (6a″) is true at (w, k).

(6a″) $PR_p(win(max, race))$

This is the case if and only if (a) $[\![win(max, race)]\!]^{\langle M,g\rangle} \in E$ and $g_c(p) \in Pr$ and (b) for all indices $(w', i') \in W \times I$, if $win(max, race)$ is true at (w', i'), then there is an interval j' such that i' is the final bound of j' and $g_c(p)$ is true at (w', j'), and (c) $g_c(p)$ is true at (w, k).

Now the truth of $g_c(p)$ with respect to $\langle M, g\rangle$ at (w, k) is consistent with the formula $win(max, race)$ being false at all times in w. So suppose $win(max, race)$ is false at all times in w. Then sentence (7a) is false in M at (w, i).

(7a) $PAST_{(v,t)}(win(max, race))$

But this is the logical form of (7). Hence (6) does not entail (7).

The semantics of $PROG$ provides an explanation of the entailment from (14) to (15).

(14) Max was running

(15) Max ran

The logical form of (14) is (14a), and the logical form of (15) is (15a).

(14a) $PAST_{(v,t)}[PROG(run(max))]$

(15a) $PAST_{(v,t)}(run(max))$

We can show that the truth of (14a) in a model M at an index (w, i) entails the truth of (15a) at (w, i). For suppose that (14a) is true in a model M at (w, i). Then $g_c(v) = w$, $g_c(t) = i$, and $[PROG(run(max))]$ is true at an index (w, j) where $j \ll i$; so $[\![run(max)]\!]^{\langle M,g\rangle} \in Pr$, and there exists a closed interval k such that j is a proper subinterval of k and $run(max)$ is true at (w, k). By the homogeneity principle satisfied by the framework IQ, if $run(max)$ is true at (w, k), then it is also true at (w, j) since j is a proper subinterval of k. But $j \ll i$ and so (15a) is true in the model M at (w, i). Hence (14) entails (15), as required.

7.2 The Entailments from the Non-Progressive to the Progressive

Let us investigate in this section the entailments from (15) to (14), and (7) to (6). First consider sentence (7), whose formal representation is (7a).

(7) Max won the race

(7a) $PAST_{(v,t)}[win(max, race)]$

Suppose (7a) is true in the model M at (w, i). Then $g_c(v) = w$, $g_c(t) = i$ and there is an interval $j \ll i$ such that $win(max, race)$ is true at (w, j). Suppose that (non-linguistic) context provides a suitable process to $win(max, race)$ at (w, j), so this process satisfies the necessary temporal precedence relation with the denotation of $win(max, race)$. Let $g_c(p)$ be this process in (6a), the logical form of (6).

(6) Max was winning the race

(6a) $PAST_{(v,t)}[PROG[PR_p(win(max, race))]]$

$g_c(p)$ is a suitable process to $win(max, race)$ at (w, j), and so (by the temporal precedence relation) since $win(max, race)$ is true at (w, j) there exists an interval k whose final bound is j such that $g_c(p)$ is true at (w, k). Hence by the definition of PR_p, $PR_p(win(max, race)$ is true at (w, k), and by the definition of $PROG$, (6a′) is true in w at the open interior of k.

(6a′) $PROG[PR_p(win(max, race))]$

But $j \ll i$ and j is the final bound of k, so $k \ll i$ and the open interior of k is earlier than i. Hence (6a) is true at (w, i). Hence (7) entails (6) as long as extra-linguistic context provides a suitable prior process to Max becoming the winner of the race (i.e. $g_c(p)$ is defined appropriately), as required.

Problems appear to arise when one investigates whether sentence (15) entails sentence (14).

(15) Max ran

(14) Max was running

One can show that the current analysis does not account for a logical entailment from (15) to (14). I will show this by constructing a model M where (15) is true at an index (w, i) but (14) is false at (w, i). Let $run(max)$ be true in the model M only at the index (w, j) and at subintervals of j. Then let $int(j)$ be the open interior of j. Since $run(max)$ denotes a proposition from Pr, j must be closed, and so the initial bound k of the interval j is not contained in $int(j)$ and so k is earlier than $int(j)$. Furthermore by homogeneity, $run(max)$ is true at (w, k) (since k is contained in j). Now let us evaluate the truth value of (15a), which is the representation of (15), at $(w, int(j))$.

(15a) $PAST_{(v,t)}(run(max))$

(15a) is true in the model M at $(w, int(j))$ if $g_c(v) = w$ and $g_c(t) = int(j)$ and there is an interval l earlier than $int(j)$ such that $run(max)$ is true at (w, l). Assuming that $g_c(v) = w$ and $g_c(t) = int(j)$, (15a) *is true* at $(w, int(j))$ since k is earlier than $int(j)$ and $run(max)$ is true at (w, k).

However, we can show that (14a), the representation of (14), is *false* in the model M at $(w, int(j))$.

(14a) $PAST_{(v,t)}[PROG(run(max))]$

(14a) is true at $(w, int(j))$ if $g_c(v) = w$ and $g_c(t) = int(j)$ (these assignments hold by our assumption), and there is an interval l earlier than $int(j)$ such that $PROG(run(max))$ is true at (w, l). We will now show that there is no such interval l. Since $run(max)$ is true in M only at (w, j) and the subintervals of j, by the definition of $PROG$, $PROG(run(max))$ is true in M only at $(w, int(j))$ ($int(j)$ is the open interior of j) and subintervals of $int(j)$. Hence there is no interval l earlier than $int(j)$ such that $PROG(run(max))$ is true at (w, l) and so (14a) is false at $(w, int(j))$. Thus we have constructed a model M where (15a) is true at $(w, int(j))$ and (14a) is false at $(w, int(j))$, and so there is no logical entailment from (15a) to (14a). We are able to construct such a model as a direct result of the fact that $PROG(run(max))$ is true only at the *open interiors* of the interval j at which A is true, and it is not necessarily true at j itself.

In view of the apparent inability to explain why (15) entails (14), the analysis seems to be flawed. However, following Taylor (1977, 1985), one could explain away this flaw by appealing to the distinction between truth and assertability. We appeal to the hypothesis that even though in the above model M (15) is true at the open interval $int(j)$ in virtue of $run(max)$ being true at the initial bound of $int(j)$, one is not in a position to *assert* at the open interval $int(j)$ that $run(max)$ was true at the initial bound of $int(j)$. This hypothesis is motivated by the intuition that an action must go on for an *extended period* of time before one can recognise the action and so assert that it is going on. For example, one cannot tell from a snap shot taken of Max at some *singleton* $\{t\}$ (i.e. minimal interval) whether Max was running at $\{t\}$, and so one cannot *assert* that $run(max)$ is true at $\{t\}$ even if $run(max)$ *is* true at $\{t\}$. If one accepts this, then one explains that the assertion of (15) entails the assertion of (14).

Our strategy for defining the semantics of the progressive is distinct from the Eventual Outcome Strategy because the semantic definition of $PROG$ does *not* place conditions on the outcome of the current state of affairs. We do not appeal to constructs such as inertia worlds. In place of these constructs we have the temporal precedence relation between p and A in the definition of the formula $PR_p(A)$. This temporal precedence relation captures the intuition that if the event A occurs the process p must have been going on just before. So instead of defining the *effects* or *eventual outcome* of the process p, as the Eventual Outcome Strategy does in terms of inertia worlds, we define what must have happened *before* A. As a result of our departure from the Eventual Outcome Strategy, our solution to the imperfective paradox does not suffer that strategy's problems. We are able to account for the possibility that while Max is running in the race, *Max is winning the race* is true, and then false, and then true, and then Max wins the race: for there is an admissable model M where $PROG[PR_p(win(max, race))]$ is true at (w, i), false at (w, j) and true at (w, k), and $win(max, race)$ is true at (w, l) where $i \ll j \ll k \ll l$. Furthermore, by our analysis of $PROG$, PR_p and $win(max, race)$, the situation in figure 2 is inconsistent. This is because $win(max, race)$ is only true at minimal intervals, and so $PROG[PR_p(win(max, race))]$ cannot be true and then false and then true at an interval contained in one where $win(max, race)$ is true.

One may look upon our analysis of aspect as replacing Dowty's primitive function Inr in the model with another primitive function; g_c. Thus it appears that the explanatory power of our theory is no more than that of Dowty's. However, our theory is an improvement on

Dowty's in two very important respects. Firstly, the function g_c is motivated independently from the analysis of aspect, unlike Dowty's function Inr, because parameters are used to analyse all indexical expressions. Secondly, our function g_c is well-defined, and we showed that Inr cannot be well-defined without reducing the analysis of aspect to circularity. So our theory overcomes the problems encountered in Dowty's approach to aspect.

8 Conclusion

Solving the imperfective paradox consists of two tasks. The first is to represent a semantic distinction between sentences like (15) and sentences like (7).

(15) Max ran

(7) Max won the race

The second is to provide a definition of the progressive that is sensitive to this distinction and so results in a solution to the imperfective paradox. I presented an account of the semantic distinction between (15) and (7) by formulating a classification of aspect in the framework of IQ, and provided a suitable definition of the progressive that builds on this.

Two properties of IQ play a central role in the analysis of aspect. The first is the *homogeneity condition* which is fundamental to the framework IQ. Homogeneity plays a crucial role in explaining the entailment between (14) and (15), for example.

(14) Max was running

(15) Max ran

The second important feature of the analysis is the role played by *parameters*. In using parameters we capture the intuition that extra-linguistic context determines exactly what process an utterance like *Max was building a house* denotes.

I offered an account of the entailment from (14) to (15), and at the same time showed why no such entailment holds between (6) and (7).

(6) Max was winning the race

(7) Max won the race

I also offered an account for why (15) entails (14) and (7) entails (6), and thus I solved the imperfective paradox.

In the first part of this paper, I exposed irresolvable problems in attempting to solve the imperfective paradox with the Eventual Outcome Strategy, but our definition of the progressive is not subject to these problems; it is wholly distinct from the Eventual Outcome Strategy. So our solution to the imperfective paradox transcends the problems encountered in previous theories.

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