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A Cognitive Analysis of Event Structure

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Abstract

Events occupy a central place in natural language. Accordingly, an understanding of them is crucial if one is to have any kind of a theoretically well-motivated account of natural language understanding and generation. It is proposed here that speakers create a cognitive structure for each discourse and process it as they introduce sentences into the discourse. The structure for each sentence depends systematically on its tense, aspect and the situation type; its effect on the discourse also depends on the structures of the sentences that precede it. It is also argued that the perfective aspect introduces the structure of the given event in its entirety. The progressive, by contrast, introduces only the core of the structure of the given event excluding, in particular, its preparatory processes and resultant state. Similarly, the perfect and the perfective can be distinguished on the basis of the temporal schemata they introduce. While the perfective presents the event as complete, the perfect presents it as complete and closed; i.e., the perfect prevents succeeding discourse from being interpreted as falling during the given event. This is surprising since the perfect is otherwise simply the combination of the perfective and a tense. This paper also provides a key motivation for distinguishing between the preparatory processes and the preliminary stages of an event. This observation, which is crucial in distinguishing between the perfective and the progressive has not been made in the literature.

Contents

1 Introduction

The issues of the ontology of events, of how they are represented by human speakers and hearers of natural language, of how they are referred to by different sentences and of the kinds of temporal relations that exist or are perceived among them are all matters of great importance in the fields of Linguistics and Cognitive Science. How these issues are resolved would also have great significance in the Computational Linguistics and Artificial Intelligence research communities as well, where designing natural representation of events is a critical first step in building programs to understand and generate natural language. A semantically well-motivated analysis of events would not only describe how individual sentences describing events are structured, but also how they interact in discourses. It is interesting to note that many of the required features of sentences become clearer when the bigger picture, i.e., discourses, are considered.

One of the problems that motivates the research described herein concerns the temporal relations that exist, or can be inferred, between the events described by the successive sentences in a discourse. This problem is especially interesting in cases where the sentences themselves lack any explicit indicators of their relative ordering. This problem has been addressed previously by many researchers, who seem to think that an immediate introduction of pragmatics is required [Dowty, 1986; Lascarides and Asher, 1990]. I hope to show that a large part of the problem is dissolved when complex representations for events such as those proposed in this paper are used.

Another, somewhat related, problem is of the semantics of the so-called *when-clauses*. When-clauses, e.g., in sentence 1 due to Ritchie [1979], seem to allow all possible temporal orderings of the main and subordinate clauses, depending on what those clauses are.

1. When they built the 39th street bridge, ...
   a) A local architect drew up the plans.
   b) They used the best materials.
   c) They solved most of the traffic problems.

This problem has also been studied by Moens and Steedman. The explanation provided by them is that each event has a nucleus which includes the preparatory process and the resultant state of the event. This idea is related

to the temporal schemata introduced by Smith [1991]. Moens and Steedman interpret sentence 1a as referring to the preparatory process of the building of the bridge, sentence 1b as referring to the actual building of the bridge and sentence 1c as referring to the resultant state. The choice is made purely on pragmatic knowledge [Moens and Steedman, 1988].

In this paper, I accept many of the intuitions of Smith and of Moens and Steedman about the structure of events, but develop a more fine-grained analysis than their respective theories. I motivate a more elaborate structure of events of different *situation types* (which I describe shortly). These structures I call the *temporal schemata* of the given events. I also introduce the concept of a *foil* as distinct from the structure that exists for each event as described by the speaker. A foil describes a structure created from a sequence of sentences and more closely matches the structure of the described events, as they are *introduced* into the discourse by the speaker. While the schema of an event describes it as standing by itself, the foil of a discourse describes the information about the events that the participants of the discourse have extracted from it. The events described by successive sentences in a discourse are integrated into the foil that already exists for the discourse as it has progressed so far. Note, however, that not every part of the schema of an event in a discourse need be included in the foil that is generated. Intuitively, a temporal schema is like a transparency that may be slid into position on top of the existing foil in any of a limited number of ways.[1]

In the analysis I propose, every event type has an associated temporal schema. The exact structure of the temporal schema of an event depends crucially on its situation type and the viewpoint aspect that the speaker chooses to represent it with. Every sentence brings along a temporal schema which may be all or a part of the situation. The temporal schema may be understood as a cognitive representation of the event type in the speaker's and the hearer's mind. Though the tense of a sentence is important in locating the event with respect to the time of the utterance, I do not consider it in detail here.[2]

[1] Hence the term "foil." To those for whom the connection to Discourse Representation Theory of [Heim, 1982; Kamp, 1984] is obvious, a foil is just a file, pronounced with a New Jersey accent.

[2] English has three tenses namely, past, present and future. Some languages divide time only into past and non-past; future and non-future and so on. Since English has a three

In §2, I provide a description of the situation types taken from Smith, which extend the classification proposed by Vendler [Vendler, 1967]. In §3.1, I give a brief introduction to the different possible aspectual classes. In §3, I motivate a general theory, which I call *foil theory*, to capture the cognitive basis of temporal reference. In §3.2, I present a cognitive analysis of the perfective aspect and temporal ontology. In §3.3, I present an analysis for the progressive. In §3.5, introduce the grammatical categories of the perfect and the futurate. In §3.6, I distinguish between the foils introduced by the perfective and the perfect.

2 The Structure of Situations

2.1 Situation Types

Each sentence may be seen as characterizing a *situation* [Smith, 1991]. It is customary, following Vendler, to divide situations into the categories of *states* and *events* [Vendler, 1967]. States are non-dynamic situations that hold homogeneously, e.g., "know German," "be tall." Events are dynamic situations and may be homogeneous or heterogeneous. Event types are further divided into *activities*, e.g., "walk in the park," any part of which is also walking in the park, *achievements*, e.g., "win a race," which is instantaneous and *accomplishments*, e.g., "build a house," which is the action of building, terminating in the completion of the house. Another category of events is that of *semelfactives*, e.g., "to hiccup," which are instantaneous like achievements, but unlike them do not have any well-defined resultant states (in the viewpoint of the speaker). These are included in the diagram of event types given in Figure 1 only for completeness—they are sufficiently like achievements to not merit separate discussion in this paper.

Sometimes, situation types are also called the *aspectual classes* of the given sentence. It is often convenient to refer to achievements and accomplishments as *telic* events and to activities as *atelic* events. Telic event types have a natural final endpoint; e.g., the building of a house is over when the house has been built and the reaching to the top is over when one arrives there. By contrast, atelic events may end at any time, i.e., they have arbi-

way distinction, I base the present analysis on this maximal subdivision of time.

trary final endpoints only. The temporal schemata of different types of events are depicted as follows by Smith [1991]. Here, I denotes the *initial endpoint* of an event, F_N the *natural final endpoint*, F_A an *arbitrary final endpoint*, R the *result state*, ellipsis continued action and parentheses optionality.

2. **Achievements:** $(I)\ (\ldots)\ F_N\ (R)\ \ldots$
3. **Accomplishments:** $I\ \ldots F_N\ (R)$
4. **Activities:** $I\ \ldots F_A$

It does not make sense to give a temporal schema for states since they neither have endpoints and are not dynamic. They merely hold for periods of time as events occur. An important characteristic of states is that they hold over intervals. For example, "John knows French" is a proposition that holds over an interval since John last learned it and till he forgets it. At best, states can be depicted temporally as in 5 below.

5. **States:** .....

In general, the main bases for classifying situation types are their duration, (i.e., whether they are instantaneous or durative) and whether they have culminations. The resulting classification is shown in Figure 1. Krifka classifies situation types also on the basis of the manner in which the object may be affected and so on. These subclassifications provide important insights into the study of tense and aspect but, for the purposes of this paper, I assume the coarser classification presented in Figure 1. The reader is encouraged to see [Krifka, 1989; Krifka, 1991] for details of his classification.

	DURATIVE	INSTANTANEOUS
CULMINATED	Accomplishments	Achievements
UNCULMINATED	Activities	Semelfactives

Figure 1: Classification of Event Types

In the rest of this section, I present a more elaborate structure of the temporal schema that I argue is required to talk of temporal reference. The schemata for each situation type are defined independently of the aspect. The aspect supplies a further filter on these schemata in ways that are described in §3.

2.2 Accomplishments

To be able to interpret narrative discourse temporally, we must provide a more elaborate structure for events than the simple one described in §2. Moens and Steedman present one such structure that they call the *nucleus* of the given event. For culminated event types, namely, accomplishments and achievements, they propose the schema diagramed in Figure 2 [Moens and Steedman, 1988].

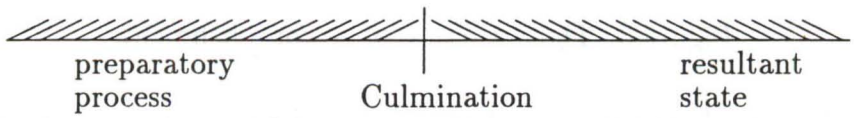

Figure 2: Nucleus of Culminated Event Types

Unfortunately, the Moens and Steedman approach, while more elaborate than the traditional one, still has some limitations. As I will show later in this paper, these limitations arise from their (1) treating the perfect as applicable only to culminations, (2) treating the progressive as being applicable only to processes, (3) not treating the perfective separately from the perfect and (4) not distinguishing the preparatory processes and the preliminary stages of an event. I will concentrate here on the proposed approach, and compare it where appropriate with Moens and Steedman's.

In order to capture the relevant properties of accomplishments, I propose the schema diagramed in Figure 3. As I go along I will explain the motivations for including various details, e.g., the various subevents of the actual event, the distinction between preparatory processes and preliminary stages, and so on.

In Figure 3, I is the initial endpoint, i.e., the point at which the event begins. F_N is the natural final endpoint of the event. This refers to the point where the event would end naturally. For example, the natural final endpoint of the predicate "drinking a glass of beer" is when the beer in the glass has been consumed (and the drinking of the same glass of beer can go on no longer). The events e_1, e_2, etc., are the *subevents* of E. F_A refers to an arbitrary final endpoint of E. These endpoints are more naturally found in telic events that have a long duration. For example, "to build a

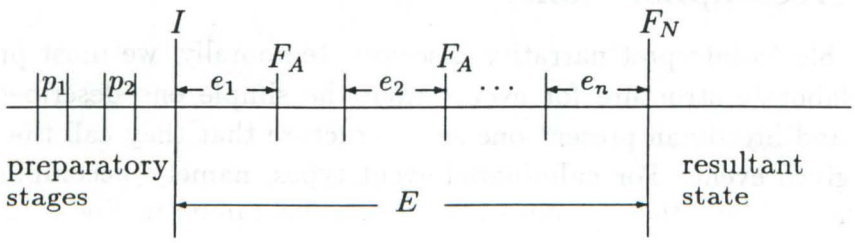

Figure 3: The Structure of Accomplishments

bridge" is a predicate that is likely to take time. And it is natural that all the building will not take place at once. The event of building can be broken down into smaller subevents, e.g., the events of building from 8 am to 5 pm every weekday. It may, alternatively, be broken into the subevents of setting up the iron bars, adding the concrete and so on. These subdivisions can be based on any factor (e.g., time, mode of construction, kinds of labor employed) and can be made as fine-grained as needed. The endpoint of any such subevent is an arbitrary endpoint. Therefore each telic event can be characterized as referring to at least the join of all its subevents.

In addition to the actual event it is possible to have subevents or states that could be classified as belonging to the preparatory process or the resultant state of the event. For example, consider again the event of building a bridge. The actual construction of the bridge falls between I and F_N, but subevents like getting a loan, drawing up the plans, etc., will be parts of the preparatory process. The resultant state refers to the state that holds after the bridge has been constructed. The structure presented in Figure 3 above is the entire temporal schema of an accomplishment; possibly, only some parts of it may be represented in a discourse.

2.3 Achievements

Achievements are quite like accomplishments, but differ from them in that they are instantaneous and do not require an obligatory process leading to the culmination. For example, "spot a cat" is an achievement, which does not require any preparatory process. There are, on the other hand, events

that are achievements requiring some activity before the achievement takes place. For example, "win a race" is a predicate that at least requires that the participant do some running before he can win the race. Unlike for accomplishments, a proper subevent of the achievement cannot be called "winning the race," because the predicate "win" applies only to the point at which the race is won.

A major characteristic of achievements that distinguish them from accomplishments is that their preliminary processes are detachable. In the case of an accomplishment such as "building the house," all subevents of the building process may be referred to as "building the house." The same is not true of an achievement such as "winning the race." The temporal schema of an achievement may be depicted as in Figure 4 below.

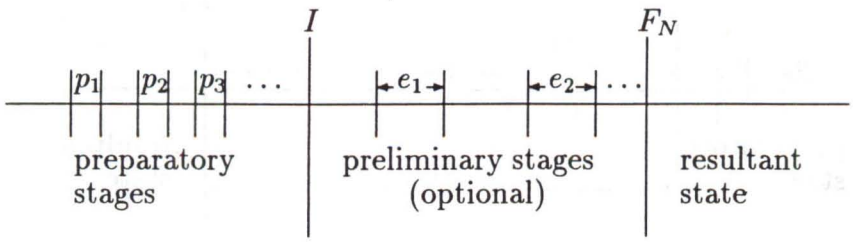

Figure 4: The Structure of Achievements

2.4 Activities

Activities are homogeneous events that do not have any natural endpoints and, therefore, can end at any time. But, like accomplishments, activities can comprise of smaller events and preparatory processes as well. For example, consider the discourse presented in text 6.

6. When John collected sea shells on the beach,
   a) He badly needed a break from his work.
   b) He collected many kinds of sea shells.
   c) He had to wear his glasses.
   d) He was relaxed.

We may have reference to the preparatory process and the resultant states just as we did in the case of accomplishments and achievements. In the text presented above 6a and 6c refer to the time before John actually collected any sea shells. 6b refers to the subevents of the activity and 6d refers to the resultant state that obtained after the end of the activity. The fact that reference can be made to intervals that lie before or after the actual walking event shows that preparatory processes and resultant states are not restricted to the class of culminated events. Rather, as will become clear in §3 they result from the aspect that the speaker uses to represent the situation. This motivates the temporal schema for activities diagramed in Figure 5.

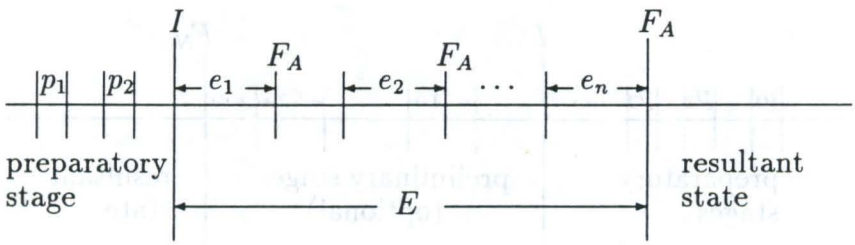

Figure 5: The Structure of Activities

3 Foil Theory

While a schema is the maximal representation of an event only parts of it are introduced into the discourse. It is these parts that I call the foil. A sentence may or may not introduce a new foil. A new foil is introduced obligatorily for *when-clauses*, adverbial clauses, and when the temporal schema of a sentence does not fit in with the existing foil (either semantically or pragmatically). The crucial idea is that aspect is what the speaker uses to refer to the event, and with which the speaker can introduce all or part of the situation into the discourse. In the subsections that follow I explain how the foil is constructed for a discourse and how the text is interpreted semantically.

3.1 Aspect

Aspect is best defined as the viewpoint of the speaker towards a situation. Aspect is usually divided into two kinds: the *perfective* and the *imperfective*. The perfective aspect describes the situation as a complete whole (e.g., sentence 7), without any reference to its internal dynamics. The imperfective aspect is a view of the situation internally (e.g., sentence 8). For example, while sentence 7 presents the event of eating an apple as a whole, sentence 8 presents the situation as an ongoing event.

7. John ate an apple.
8. John was eating an apple.

Though the definition of the perfective seems fairly straightforward, at this point I would like to mention that there is some ambiguity in it. It has been suggested by Comrie that the real definition of the perfective ought to specify the given action was complete, rather than completed [1976]. This distinction is not as important in English as it is in many other languages, e.g., Hindi, Japanese, and Chinese. The temporal relations in these languages are a little different from those in English because the *neutral perfective* aspect [Singh, 1991] introduces a foil that is different from the foil introduced by the perfective. However, in this paper I present an analysis only of the common perfective.

3.2 The Perfective Aspect and Foil Theory

When a situation is introduced by a speaker into a discourse, its temporal schema becomes available (as the initial foil) for temporally locating successive sentences. In cases where an event is introduced by a sentence in the perfective, the entire temporal schema becomes available. If the sentences that follow are also in the perfective aspect, they add their schemata to the existing foil. As an example, consider Figure 6, which is a diagrammatic representation of the three versions of sentence 9 below.

9. When they built the 39th street bridge ...
   a) A local architect drew up the plans.
   b) They used the best materials.
   c) They solved most of the traffic problems.

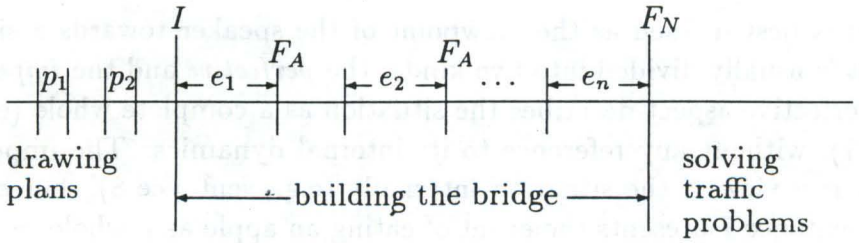

Figure 6: Interaction of Events Represented in the Perfective Aspect

From the various interpretations possible for the perfective, we may conclude that the perfective introduces a foil that includes the *entire* temporal schema of the event. Succeeding sentences of the discourse may refer to any subevent of the foil or to the *join* of any of them. In the algebraic semantics of events due to Krifka that I adopt here, a set of events is distinguished in the model. The *join* (notated $\sqcup$) is a binary operator on events that yields new events—the set of events must be closed under this operator. Intuitively, the join of two events represents their mereological sum. If the two argument events have certain spatio-temporal histories, their join has a history which is a union of those histories; if the events affect certain objects, the join affects them too. It is perhaps obvious that join is associative, i.e., $(e_1 \sqcup e_2) \sqcup e_3 = e_1 \sqcup (e_2 \sqcup e_3)$. Please consult [Krifka, 1989; Krifka, 1991] for further details.

Returning to the example at hand, sentence 9a refers to the subevent $p_1 \sqcup p_2$ introduced on the foil by the *when-clause*. Sentence 9b may refer to $e_1 \sqcup e_2 \sqcup e_3$, i.e., to the join of all the subevents in which the actual building of the bridge took place. Sentence 9c may refer to the resultant state R.

3.3 The Progressive Aspect and Foil Theory

To characterize the case of the progressive properly, I shall first discuss discourses initiated with a sentence in the progressive and the those which are initiated by a perfective and followed by those in the progressive.

10. When they were building the bridge,
    a) They were using the best materials.
    b) They were solving their traffic problems.
    c) A local architect was drawing up the plans.
11. When they were building the bridge,
    a) They used the best materials.
    b) They solved their traffic problems.
    c) A local architect drew up the plans.

In the discourse presented in example 10, the foil is introduced by a sentence in the progressive. I submit that if the speaker chooses to use the progressive viewpoint aspect, then he voluntarily brings into the discourse only a part of the representation of the introduced event. That is, it automatically excludes the preparatory process and the resultant state from the temporal schema of the event. What remain are the subevents of the core event, in the above example, the actual building of a bridge. These are all that is available to the speaker. All subsequent references to the introduced event are then references to a part of the schema introduced previously. As the discourse proceeds, the speaker may refer to any of the subevents and *their* preparatory processes or resultant states. This is an important point, because while the preparatory processes and resultant states are not available for the entire event, they are used for the internal subevents.

Consider the following examples, where the first sentence is in the perfective but the next one is in the progressive.

12. When John ate apples,
    a) He was talking to Bill.
    b) He was feeling unwell.
    c) He was hungry.
13. When John was eating apples,
    a) He was talking to Bill.
    b) He was feeling unwell.
    c) He was hungry.

In discourse 12, since the foil is introduced by a sentence in the perfective aspect, subsequent discourse can be anchored to any part of it. That is,

sentence 12a implies overlap of the activity of talking with the event of eating apples; sentence 12b implies that the state holds at the time of eating; and sentence 12c implies that John was hungry before he ate apples (using the pragmatic rule of causality).

However, in discourse 13, where the temporal schema is introduced with the progressive aspect, only the actual event is available. Subsequent discourse has to be anchored to it, and not to its preparatory stage or resultant state. Therefore, sentence 13c cannot have the interpretation that John was hungry before he ate the apple. Rather, it means that John was hungry for *some* subevent of the eating of the apples.

3.4 Preparatory Process and Preliminary Stages

In the examples presented in §2, I distinguished between the *preparatory process* and the *preliminary stages*. It may not seem very clear at the outset where the line should actually be drawn between these two concepts; e.g., it might seem that the preliminary stages of an event are merely the preparatory processes for the rest of it and the preparatory processes of an event are the preliminary stages of the greater event. However, it is easy to see that the distinction is principled from at least the linguistic standpoint. Consider the case where the first sentence, i.e., the one which introduces the foil, is an achievement. In text 14 below, the initial sentence is in the perfective aspect; in text 15, the initial sentence is in the progressive aspect.

14. When John won the race, he took steroids.

15. When John was winning the race, he took steroids.

The interpretation of the discourse in 14 is that John took the steroids before the actual running commenced, i.e., during the preparatory process. This interpretation is most easily obtained if one invokes the pragmatic rule of enablement with the view that it was taking steroids that made it possible for him to emerge victorious in the race. In the discourse in 15, however, the taking of the steroids is forced to have the interpretation of having taken place during the running because the preparatory process is not brought forth on the foil by the progressive aspect. The pragmatic rule cannot help push the taking of the steroid event before the running event because of restrictions

on temporal reference imposed by the foil theory. This is important because while the notions of preparatory stages and preliminary processes have been thought to be important in the literature [Moens and Steedman, 1988; Smith, 1991], no justification of their definitions and of the distinction between them has been available.

3.5 The Perfect and the Futurate

The perfect and the futurate are two of the categories known from traditional grammar. However, they are each more complex than the tense and aspect categories and have features of both. The perfect is a combination of the perfective aspect and a tense. The tense of a perfect construction may be the present or the past. The perfective aspect and present tense is the simple perfect or the present perfect. The perfective aspect and the past tense is the past perfect. The futurate is the perfective aspect and the future tense. The categories of perfect and futurate are special in some ways for our purposes also.

It was first noted by Reichenbach that the grammatical category of the perfect alludes to three points, namely, the *reference time* (RT), *speech time* (ST) and the *event time* (ET) [Reichenbach, 1947]. Briefly, ST is the time at which the given utterance is made, ET is the time at which the described event occurs and RT is the time from the standpoint of which the event is described. With various combinations of these times, we can arrive at the general schema for the present perfect, past perfect and the futurate. In a sentence in the present perfect, e.g., 16, the ST and the RT are the same and the time of the event referred to precedes the time of speech. This is shown in Figure 7.

16. John has won the race.

As mentioned above, the perfect can also be used in the past, not just in the present. For example, consider sentences 17 and 18. The past perfect suggests that there is a reference time, namely, yesterday such that at that time Henry had the property of having danced or having eaten an apple, respectively. In particular, it requires that Henry still exist as a separate entity at the reference time, i.e., be alive then.

17. Henry had danced yesterday.

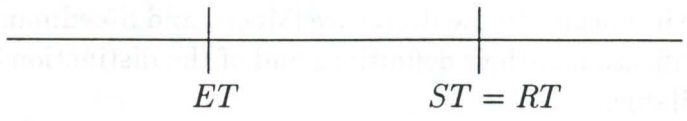

Figure 7: Temporal Schema for the Present Perfect

18. Henry had eaten an apple yesterday.

The futurate occurs only in the future and is exemplified in sentences 19 and 20 below. The futurate implies that there will be a time such that Henry will have the attributes of having danced or having eaten an apple. Because of its close resemblance with the perfect, the futurate is sometimes also called the *Future Perfect.*

19. Henry will have danced tomorrow.
20. Henry will have eaten an apple tomorrow.

The schemata for the past perfect and the futurate as given by Reichenbach are presented in Figures 8 and 9, respectively.

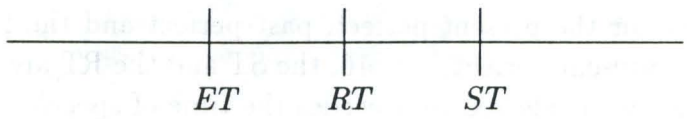

Figure 8: Temporal Schema for the Past Perfect

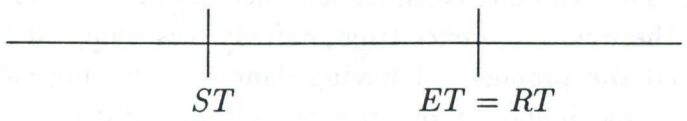

Figure 9: Temporal Schema for the Futurate

3.6 The Perfective versus the Perfect

While the perfective is subsumed in the categories of the perfect and the futurate, there are still some reasons for studying it by itself. These include the following. The perfect is not an aspectual category; rather, it is a grammatical category that many natural languages employ to relate an event to a reference time. For example, sentence 21 is in the perfect, and as a result of being in the perfect, its subject i.e., 'John,' is attributed the property of having won the world championship. The perfect would imply that at the reference time, (which equals the speech time) the property of having won the world championship applies to John. But if the situation happens to be such that Bill died in a car accident after he won the world championship, then the simple perfect will no longer hold though the perfective will. For example, sentence 22 will be true at all times after the winning has taken place. In general, the perfect can be interpreted as being a statement of the attribution of a property to an individual. The attribution essentially holds till the reference time but may not hold after that. In the case of the perfective, since there is no such attribution, the truth value will be the same at all subsequent times. The temporal schema for the present perfect is given in Figure 10.

21. John has won the world championship.
22. John won the world championship.

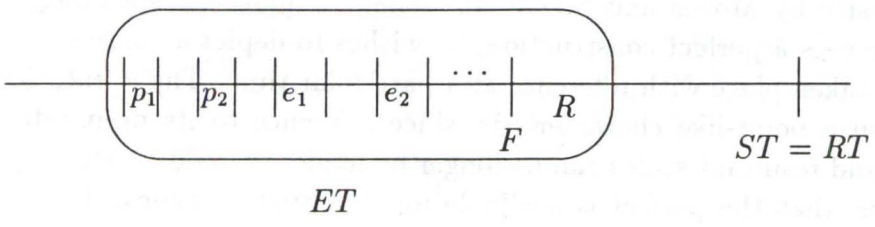

Figure 10: The Structure of the Present Perfect

One important difference between the perfect and the perfective is the following. The perfect tends to seal off the temporal schema of the event it

introduces, making it difficult to refer to events or times inside it with later sentences. Thus while all the combinations in sentence 1 are grammatical, the corresponding cases with the perfect replacing the perfective in the main clause are not. It seems that while each case in sentence 23 is ungrammatical, it could be made grammatical by using the perfect consistently in all the subordinate clauses, as in sentence 24. Interestingly, in sentence 24, the event time of the when-clause becomes the reference time for the succeeding subordinate clause. Since these times may be intervals rather than points, it is possible that they overlap in time.

23. When they had built the 39th street bridge, ...
    a)* A local architect drew up the plans.
    b)* They used the best materials.
    c)* They solved most of the traffic problems.
24. When they had built the 39th street bridge, ...
    a) A local architect had drawn up the plans.
    b) They had used the best materials.
    c) They had solved most of the traffic problems.

At this point I would like to emphasize that since the perfect is a combination of the perfective and a tense (past, present or future) there is a *tendency* for it to occur with culminated events. This tendency has been viewed as a necessity by Moens and Steedman [1988]. Cognitively speaking, when a speaker uses a perfect construction, he wishes to depict a complete event as having taken place with reference at a particular time. The event, therefore, takes on a point-like characteristic, since reference to its preparatory processes and resultant states can no longer be made. I would like to emphasize, however, that the perfect is available for *all* situation types. Consider the following examples.

25. Mary has known French. (state)
26. Mary has swum in the pond. (activity)
27. John has built a house. (accomplishment)
28. John has won the race. (achievement)

It seems that the only reason why examples of unculminated events provided by Moens and Steedman seem wrong is that they do not have pragmatically correct attributes. Consider, for example, sentences 29 and 30 provided by them as being ungrammatical.

29. John has hummed.

30. The clock has ticked.

The reason why these are ungrammatical is that the subject cannot be very easily attributed the property of having hummed (as in sentence 29) or having ticked (as in sentence 30). It might, however, be possible to attribute the property of having knocked at the door (which too is a semelfactive) as in sentence 31.

31. John has knocked at the door.

Sentence 32 below is also grammatical since one can felicitously attribute the property of having ticked a particular time to a clock.

32. The clock has ticked 6 o'clock.

The basic idea here is that the property we attribute to the subject must be special or, at least, be an attributable one. The greater the pragmatic relevance of the attribution, the better the grammaticality of the sentence. My basic claim, then, is that the perfect is no way restricted to telic events. The perfect essentially depicts the event as an unanalyzed whole, thereby presenting it as momentous.

4 Conclusions

The temporal ontology of events and the effects of the sentences in a discourse on the cognitive states of the participants are both important issues. In this paper, I have presented a view of events that sees the contributions of the sentences that describe them on the cognitive states of the participants as their most significant feature. This contribution is intimately related to both the objective properties of events and to the perspectives on them taken by the speakers of the sentences.

The main idea of this paper is that each individual sentence is associated with a temporal schema and each discourse in any given state is associated with a foil. The foil of the discourse as it has progressed to a certain point constrains the contributions made by the schema of the next sentence; however, the schema of a sentence can itself be determined without reference to the sentences surrounding it. This simple idea can then be used to motivate a principled distinction on cognitive grounds between the perfective and the progressive aspects, as well as between the perfective and the perfect, which is an important category from traditional grammar. The same idea also yields a clear distinction between the preliminary stages and preparatory processes of an event.

References

[Comrie, 1976] Comrie, Bernard 1976. *Aspect.* Cambridge University Press, Cambridge, UK.

[Comrie, 1986] Comrie, Bernard 1986. *Tense.* Cambridge University Press, Cambridge, UK.

[Dahl, 1985] Dahl, Östen 1985. *Tense and Aspect Systems.* Basil Blackwell, Oxford, UK.

[Dowty, 1986] Dowty, David 1986. The effects of aspectual class on the temporal structure of discourse: Semantics or pragmatics? *Linguistics and Philosophy* 9(1):37–62.

[Grasso *et al.*, 1990] Grasso, Ennio; Lesmo, Leonardo; Lombardo, Vincenzo; Maccario, Pia Maria; Salato, Roberto; and Terenziani, Paolo 1990. Semantic interpretation of tense, actionality and aspect. In *European Conference on Artificial Intelligence*, Stockholm. 320–325.

[Heim, 1982] Heim, Irene 1982. *The Semantics of Definite and Indefinite Noun Phrases.* Ph.D. Dissertation, University of Massachusetts, Amherst, MA.

[Kamp, 1984] Kamp, Hans 1984. A theory of truth and semantic representation. In Groenendijk, J.; Jansenn, T.; and Stokhof, M., editors, *Truth,*

Interpretation and Information. Foris Publications, Dordrecht, Holland. 1–41.

[Krifka, 1989] Krifka, Manfred 1989. Nominal reference, temporal constitution and quantification in event semantics. In Bartsch, R.; van Benthem, J.; and van Emde Boas, P., editors, *Semantics and Contextual Expressions.* Foris, Dordrecht, Holland.

[Krifka, 1991] Krifka, Manfred 1991. Thematic relations as links between nominal reference and temporal constitution. In Sag, Ivan and Sabolcsi, Anna, editors, *Lexical Matters.* Chicago University Press, Chicago. In Press.

[Lascarides and Asher, 1990] Lascarides, Alex and Asher, Nicholas 1990. Discourse relations and common sense entailment.

[Moens and Steedman, 1988] Moens, Marc and Steedman, Mark 1988. Temporal ontology and temporal reference. *Computational Linguistics* 14(2):15–28.

[Nerbonne, 1986] Nerbonne, John 1986. Reference time and time in narration. *Linguistics and Philosophy* 9(1):83–95.

[Reichenbach, 1947] Reichenbach, Hans 1947. *Elements of Symbolic Logic.* Macmillan, London, UK.

[Ritchie, 1979] Ritchie, G.D. 1979. Temporal clauses in English. *Theoretical Linguistics* 6:87–115.

[Singh, 1991] Singh, Mona 1991. The perfective aspect—an algebraic analysis. Paper read at the Conference on Mathematics of Language.

[Smith, 1983] Smith, Carlota S. 1983. A theory of aspectual choice. *Language* 59:479–501.

[Smith, 1991] Smith, Carlota S. 1991. *The Parameter of Aspect.* Reidel - Kluwer. In press.

[Vendler, 1967] Vendler, Zeno 1967. *Linguistics in Philosophy.* Cornell University Press, Ithaca, NY.

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