Events and temporal types

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Propositions are types, with elements acting as warrants for their truth. Here such an element is a function.

Events in philosophy

Donald Davidson represents events in a first-order system:

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Donald Davidson represents events in a first-order system:

- Jones buttered the toast with a knife.
- $\exists e[BUTTER(Jones, toast, e) \& WITH(knife, e)]$
- $\exists e[BUTTER(e) \& AGENT(Jones, e) \& THEME(toast, e) \& WITH(knife, e)]$

Peter Hacker objects

The ideal of displaying the meaning, in particular the entailments, of sentences about events as wholly or even largely a function of structure as displayed in the canonical notation of the predicate calculus is chimerical. (Hacker 1982, p. 485)

Problematic cases?

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- There was an event which was a moving done by her and done scarcely.
- There was an event which was an apologising done be her and done wisely.
- Doesn't imply 'He was often drunk'.

There are no straightforward rules for translating ordinary event-recording sentences into the canonical notation in advance of displaying and analysing their logical structure, not in the forms of the predicate calculus, but in terms of the verbs (and their specific meanings), the qualifying adverbs (and their specific significance, and hence effect upon the overall meaning of the expression or expressions they qualify), the application of the nominalizing operation to different types of adverbially qualified verbs, etc. (Hacker 1982, pp. 485-486)

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- Computer science has temporal logics, such as CTL^*, event calculi, etc.
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- Perhaps we need some temporal (modal) dependent type theory.

Linguistics - evidence of acceptability

- He broke the plates...
- *She swept the crumbs...

The second perhaps feels incomplete.

Linguistics - evidence of acceptability

- *He broke the plates off the table.
- She swept the crumbs off the table.

The first now seems wrong.

Parsing and Implicature

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Implicature:

- *Kim took a key out of her bag and opened her front door.*
- Did she use the key?
- Did these events happen on the same day?

Parsing

- It took me two days

Parsing

- It took me two days to learn to play the Minute Waltz

Parsing

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- Finally, there is the *accomplishment* of learning to be able to perform such a feat. There is a preparatory process lasting two days which culminates in the acquisition of this ability. A new state.

Vendler's events

The philosopher Zeno Vendler proposed four event types:

1. **Goalless activities**, such as playing in a park, or repeatedly jumping;
2. **Achievements** marking moments of reaching some goal, such as arriving in Beijing, or closing the deal;
3. **Accomplishments** include the activity leading to the culmination of a goal, such as running three miles, or emptying one's plate;
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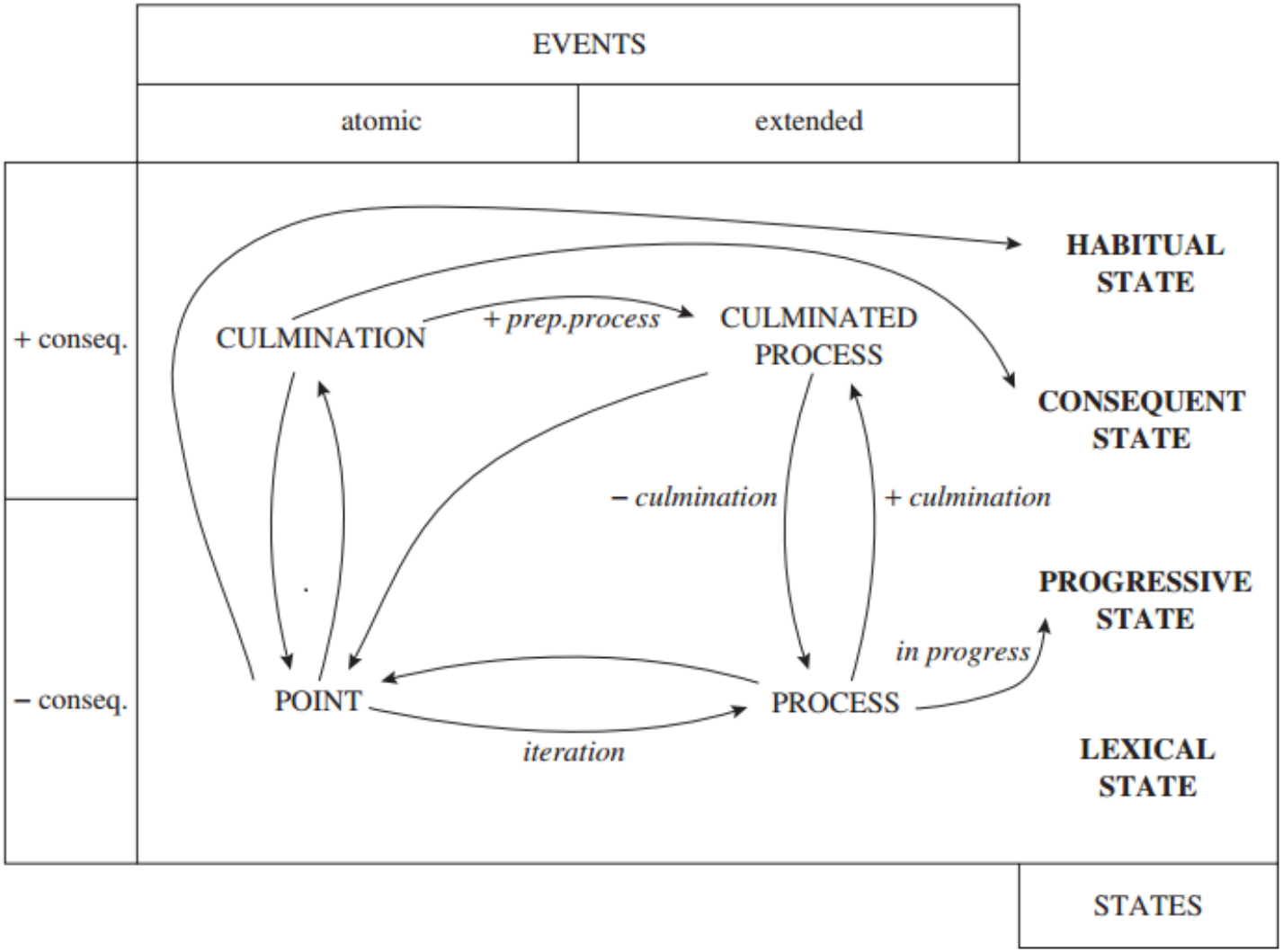
5. **Momentaneous event** a stumble, a sneeze, a flash (a further event type, Emmon Bach)

Alternative terms

- Process = Activity
- Culminated process = Achievement
- Culmination = Accomplishment
- Point = Momentaneous event

Moens and Steedman



Playing the Minute Waltz in 60 seconds

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Mappings of types?

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Psychologists study our interpretation of moving dots as events. We seek temporal boundaries marked by sudden changes of direction, speed,....

- *He broke the plates off the table.
- She swept the crumbs off the table.

Before adding "off the table", the first already has an achieved change of state; with the addition the second becomes an accomplishment.

Event nucleus

One way to characterise this boundary:

- Event nucleus = "an association of a goal event, or *culmination*, with a *preparatory process* by which it is accomplished, and a *consequent state*, which ensues." (Moens and Steedman 1988, p. 15)

Perfect tense

In English, the perfect tense marks a change of state as persisting to the present.

- I have spilt some coffee.
- I spilt some coffee.

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- I have spilt some coffee.
- I spilt some coffee.
- *I have spilt some coffee but it's been wiped up now.
- I spilt some coffee but it's been wiped up now.

Reichenbach's topic and speaker time are useful here.

- Actitivities and accomplishments have a duration (marked by ‘for’ and ‘in’).
- Achievements and momentaneous events last an instant (although there are gradual achievements).

He is travelling to Cairo.

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A progressive sentence is true at an interval *I* if and only if *I* is a moment of time, and there exists an interval I' which contains I, and I is not an endpoint for I', and the non-progressive form of the sentence is true at I'. (Hana Filip)

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It seems that we need to tie in event types, event instances and time intervals and instants.

A modal temporal type theory?

- Propositions as some types.
- Sets as some types too.
- Modalities apply to all types.
- A possible X is not just an X which is possible.
- So we can have a future X and a past X.

Temporal types

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given by $b, e : \mathit{Time}_1 \rightrightarrows \mathit{Time}_0$, marking the beginning and end instant of a time interval.

Temporal types

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$$Interval \hookrightarrow Instant^2,$$

given by $b, e : Time_1 \rightrightarrows Time_0$, marking the beginning and end instant of a time interval.

Each arrow, b and e, generates an adjoint triple, e.g., $\sum_b \dashv b^* \dashv \prod_b$, formed of dependent sum, base change, dependent product, going between the dependent types $\mathbf{H}/Time_1$ and $\mathbf{H}/Time_0$.

Temporal modal operators

For an instant-dependent proposition, $C(t)$

- $\sum_b e^* C(t)$ will contain all instances of intervals beginning at time t where C is true at the end. If this type is inhabited it means "there is some interval beginning now and such that C is true at its end", FC, 'at some Future time C'.

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We may apply F, P, G and H to any type.

We can also look at time represented by a branching tree or a partially ordered set. This brings us to the modalities of CTL*:

- Along some path always...
- Along some path at some point..
- Along every path always...
- Along every path at some point...

Add in instant interval

$$i : Time_0 \rightarrow Time_1$$

We can now express that a property holds at an instantaneous interval.

Projections and composition

Two projections from pairs of intervals that abut,

$$p, q : Time_1 \times_{Time_0} Time_1 \to Time_1.$$

And a composition map,

$$c : Time_1 \times_{Time_0} Time_1 \to Time_1.$$

We could define a type dependent on time instants such as lightning strikes happening at a moment, $t : Time_0 \vdash L(t) : Type$.

Then we could characterise the property of an interval that it contains a lightning strike as (the inhabitedness) of $\sum_c (ep)^* L(t)$

With maps $p, q, c : Time_1 \times_{Time_0} Time_1 \to Time_1$, we can be more expressive, e.g., to capture *since* and *until*.

- $\phi S \psi := \Sigma_e(b^* \psi \times \Pi_c(ep)^* \phi)$
- $\phi U \psi := \Sigma_b(e^* \psi \times \Pi_c(ep)^* \phi)$

Then we can express of a given interval that α holds for an initial part of it, and β holds for the other part.

This has been studied (Venema 1991) in the guise of what is called the *chop* operator, C, so then $\alpha C \beta$ denotes this composite property of intervals, as in 'dinner = starter C main C dessert'.

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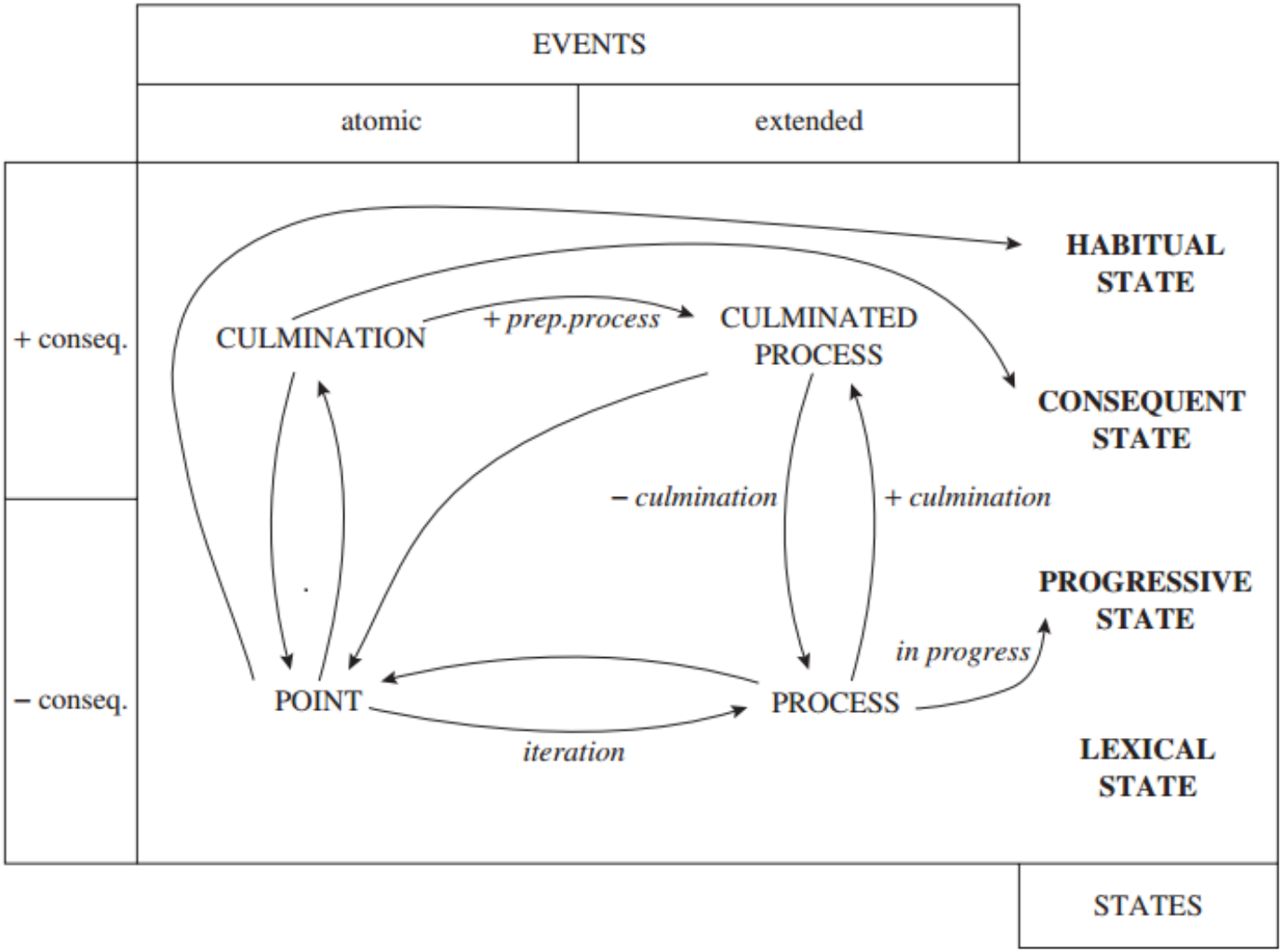
$$\alpha C \beta :\equiv \Sigma_c(p^* \alpha \times q^* \beta)$$

Event nucleus

So we can represent the event nucleus structure to be an interval of the form:

$$Activity\ C\ i^{*}(Achievement)\ C\ Changed\ state$$

Moens and Steedman



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Of course, place would need to be dealt with, and so on. We don't mean that the sneezing could take place far away.

Computer science - Linguistics - Philosophy

We have a bright future together.